SECTION II

STRATEGIC PLAN FOR SURFACE TRANSPORTATION RESEARCH AND DEVELOPMENT

CHAPTER 1

TRANSPORTATION IN 2020

Worldwide, a number of forces are converging to shape the direction of transportation over the next two decades. Understanding these changes is critical to formulating a vision and goals for transportation. Key among these global changes are significant shifts in demographics, accelerated economic growth and globalization, growing urbanization and motorization, increasing concerns for safety and security, and changing technological trends.

As we enter the 21st century, these global issues and trends will present transportation decision makers and researchers with a dilemma: how to meet the increased demand for transportation while also addressing the sometimes conflicting values of safety, security, economic productivity, environmental quality, energy efficiency, and accessibility.

In the past, changing transportation needs have typically been met through innovations in three areas: transportation vehicles; the physical infrastructure that supports their use; and the people who design, build, operate, and maintain the vehicles and infrastructure, and who plan and manage the transportation enterprise. More and more, the burgeoning demands on the transportation system will be met through a fourth means: the development and deployment of an information infrastructure that underlies transportation's physical infrastructure. In fact, on component of any strategy to meet transportation needs will in fact be a stimulation of alternatives to physical travel, where such a substitution is appropriate and effective.

Each of the four areas of innovation will be key to meeting the emerging global issues and trends discussed below and are the foundation for the planning process, partnership initiatives, enabling research, and education and training efforts that compose the above-mentioned NSTC Strategy.

II.1.a. Changing Demographics

Two major demographic changes will influence the scope and character of world transportation demand in the 21st century: population growth and the aging of the population in the industrialized world. Over the next 25 years, world population is projected to grow from its present 5.5 billion to 8.5 billion people. By far, most of this growth will be in the cities of the developing world. The increased demand for transportation for this growing population will require the expansion of existing infrastructure—highways and transit systems—and perhaps new transportation alternatives. At the same time, in the U.S. and many other developed countries, the geographic and financial resources available to build new physical infrastructure is sufficiently limited that an emphasis on efficient management and operation of existing systems, which can be facilitated through the judicious application of information technology, is vital.

While industrialized countries' populations will stabilize and perhaps even decline, there will be further aging of these populations. Today, over 12 percent of the United States' and 14 percent of Europe's population is over 65. By 2020, over 20 percent of the population in the industrialized world will be this age.

The United States alone will experience far greater growth in its elder population: an estimated 53 million people will be over 65 in the U.S. by 2020. This dramatic growth in the aging population will necessitate new approaches to transportation and mobility, among them changes in traditional transit services, transportation infrastructure, and vehicles. At the same time that this is taking place, other demographic shifts with similarly important implications for transportation demand will continue in the U.S.

For example, the increased presence of women in the workforce, which will be further encouraged by welfare reform, could further increase dependence upon private vehicles. Salaried women, more often than their male peers, shoulder the bulk of the responsibility for the day-to-day management of U.S. households, which often translates into a chained sequence of related trips to and from destinations such as workplaces, day care centers, and grocery stores.

II.1.b. The Information Technology Revolution

With rapidly increasing access to and use of personal computing technology, both at home and work, the steep rise in use of the Internet, and growth in services which permit easy access to the vast array of available electronic information, Americans are rapidly becoming accustomed to being "plugged in" in real-time. This is also leading to the expectation of access to real-time information on transportation mode choices and traffic conditions. It is also leading to changes in travel patterns, as more workers can conduct business at home or from locations other than their office, including their car or on other modes of transportation.

Historically, physical mobility has been a primary means through which people have gained access, and that mobility has been distributed primarily based on financial means. However, the creation, distribution, and use of information has become ever more central to the life of modern societies, and access to services and even employment can be increasingly be achieved through information transfer, rather than physical mobility. Of course, physical mobility will continue to be a prerequisite for many jobs, services, and leisure activities, and a variety of effects associated with telecommunications advances could stimulate travel and transportation demand. Information technology will, therefore, play a prominent role both in shaping future transportation demands, and in enabling new management and operational practices that make it easier to meet those demands in an era of constrained expansion of physical infrastructure.

II.1.c. Economic Growth and Globalization

Although there continues to be incredible poverty throughout the world, economic growth in selected regions is providing a base for the development of newly emerging upper and middle income classes. Gross domestic product per capita is steadily increasing in many countries. This trend is quite dramatic in newly industrialized countries, particularly in several Pacific Rim nations. More people have more disposable income, after paying for food, shelter, and other necessities, than in any other period in human history. This income, combined with the influence of the mass media and telecommunications, will continue to create a booming travel and tourism market. As world tourism becomes an increasing share of transportation demand, the capacity of many nations' surface and air transportation infrastructures will be strained.

In parallel with growth in international tourism and travel will be corresponding increases in international goods movement. Low-cost communication and transportation networks have already resulted in a global manufacturing and marketing enterprise. In this interdependent world economy, continued growth in international trade will increase the demand for freight transportation facilities and place increasingly stringent cost and reliability requirements on transportation networks, particularly <u>intra</u>regional networks that link increasingly dispersed networks of interconnected businesses. Coupled with this, use of information networks for "virtual" conduct of business may reduce demands for some kinds of personal travel, while simultaneously increasing demands for other kinds of passenger and freight services.

II.1.d. Urbanization and Motorization

About 45 percent of the world population currently are urban dwellers. By 2025, more than 60 percent of the projected 8.5 billion people in the world will be living in cities—many of them in megacities with populations of 10 million or more. Together with economic development, growth in the world's urban areas has led to a dramatic increase in the number of motor vehicles over the past 25 years. In 1970, there were 246 million vehicles registered in the world, 44 percent of them in the United States. By 1992, the world had 614 million vehicles, two and a half times the number in 1970, with only 31 percent in this country. In fact, the global fleet has been growing linearly since 1970, with each year bringing an additional 16 million vehicles. Should this trend continue, there would be more than 1.1 billion vehicles in the world fleet by 2025. Along with the world's growing reliance on motor vehicles has come a concomitant increase in environmental and energy impacts—global carbon emissions, petroleum consumption, air pollution, and congestion. Moreover, coupled with high population growth rates and a growing vehicle fleet, sprawling urban development is a major cause of pollution, congestion, and poverty in many of the world's cities.

In the United States, suburban sprawl has led to spatial disparities in the location of employment centers and concentrations of urban poor, who are now required to find work under the recently enacted welfare reform law. The internal migration of the population, combined with migration from abroad and with the rapid suburbanization of homes and jobs, have been linked to:

- substantial population and employment growth in the west and south;
- concentrations of migrants from abroad in a limited number of states;
- major growth in suburb-to-suburb commutes;
- major growth in reverse (i.e., urban core to suburb) commutes; and
- increased distances between home and all trip destinations.

These patterns, which vary in specific manifestation from one region to the next, have profound implications. Employees who both work and live in low density places have scattered travel patterns--they do not travel along highly concentrated corridors, and they have few alternatives to the private car when they travel. Employees who live in the core of metropolitan areas but work in the suburbs also create nontraditional commutes and may have limited travel options. Overall, these population and land use trends accelerate the travel patterns linked to the growth of a service-based economy, leading to longer work and nonwork trips, more scattered origins and destinations, and greater dependence on single-occupancy private vehicles.

II.1.e. Safety and Security of the Global Transportation System

Over the next two decades, continued growth in world transportation demand will lead to heightened concerns for transportation safety and security. For example, along with growth in automobile use will come the potential for a dramatic increase in automobile-related deaths and injuries. This is particularly true for many countries in the developing world, where the number of motor vehicles is growing far faster than the physical, legal, and institutional infrastructures needed to accommodate them. From 1968 to 1985, automobile fatalities increased by more than 300 percent in eight African countries and by almost 200 percent in six Asian nations. Even in the more industrialized countries, where safety records are typically good by historical standards, the private automobile will continue to present safety risks. Still other concerns will arise from the growth of air transportation and its increasing use for international travel. Greater demand for air travel will place additional stress on an already overburdened aviation system. As countries seek to accommodate demand by moving toward "free flight" (described further in Section II.a.3.iii) and a global infrastructure for air traffic management, questions may arise concerning the reliance on satellite and digital technologies, the increasing dependence on complex software-based aids and systems, and the need for global standards and interoperability. Moreover, the troubled state of the world and the attractiveness of aviation as a terrorist target make it likely that aviation security, as well as security in other modes of transportation, will be a major area of concern well into the 21st century.

II.1.f. Technological Trends

One clear reality of the late 20th century is the power of technology and the advances that can be achieved when it is applied in the right way, to the right problems, and in concert with more effective institutional relationships and a better understanding of the social forces that shape travel behavior, land use, and transportation needs. The magnitude and pace of improvements in the next century will depend on the investment of energy, imagination, and public and private resources made at the close of the 20th century. By 2020, advances in computer, information, and communications technologies will have dramatically changed ways of organizing and managing transportation and business activities. There will be an increasing number of potential alternatives for various transportation functions, each offering real benefits. For example, the transportation vehicles manufactured 25 years hence can be expected to offer dramatic advances in sustainability, performance, and cost, based on refinement and innovation affecting almost every component. The Administration's Partnership for a New Generation of Vehicles (PNGV) will yield significant improvements leading to lighter weight, lower cost materials, improved emission characteristics, and greatly lessened petroleum requirements. In general, technological advances will be critical factors in ensuring that the overall transportation system is brought to its full potential in terms of life-cycle economics, energy efficiency, and minimal adverse societal impacts.

The Department has conducted an environmental scan of the key technological trends which are projected for the next five to ten years, and has examined their potential impacts on the National transportation system and DOT. The general findings of this exercise are summarized below in Table II-1-1.

Trend	Impact on DOT
<u>Information</u>: Accelerated application of advanced electronics, information systems, and control systems to transportation. Over the next five years, these information-related technologies will enable the collection, management, integration, and distribution of transportation-related information in less time (< 1/100 current), with better fidelity (> 10 to 100 times more information), and broader applications. The Nation's transportation system will enter the information age.	Increasing role for DOT to set standards and guide the development of international standards for information system interfaces and electronic, safety, security, and communications systems. Increasing pressure to allow flexibility in the use of grant funds for installation or retrofit of electronic and information technologies in current and future systems. Sharing information on approaches for integrating and applying security measures on a multi-modal basis, and for maintaining closer operational links with law enforcement officials, fire departments, hospital units and the military is imperative. Will enable concurrent Federal, regional, state, and local planning, and national-level traffic management and infrastructure monitoring.
<u>Materials</u>: Stronger, lighter, and environmentally friendly advanced composites and materials will revolutionize the construction, maintenance, and repair of transportation guideways, vehicles, and systems.	Need to maintain emphasis on development and application of advanced materials established in DOT *Strategic Plan* is imperative. The benefits to transportation in the materials area are long-term. Research must be sustained in spite of increasing focus on near-term results from R&D. Need to continue leverage and apply advanced materials developed for military or aviation use in other areas of transportation. Need to incentivize the use of new structural techniques and materials in transportation systems. Need funding for the development of new and innovative materials with multi-modal applicability.
<u>Energy and Environmental Technologies</u>: New power systems, combined with lighter structures, will improve the energy efficiency and environmental compatibility of transportation vehicles. The first "sustainable" transportation systems will begin to emerge.	Improvements may generate pressure from the public and environmental groups to revisit and tighten some emissions and fuel economy standards.

<u>Human Factors</u>: Increasing knowledge and acceptance of "human-centered" system design and technology integration concepts will promote safer and more user-friendly transportation services, which are more accessible to mobility-limited users.	Coupled with increases in the population of elderly persons, the entire area of specialized or personalized transportation will have to receive greater emphasis. To assure continuing application of military and aerospace applications of human factors discoveries, closer working relationships among DOT, DOD, and NASA will be necessary. Standards for operator training will have to be reassessed on a multi-modal basis as increasing application of improved simulators to the function takes place. Modeling of individual human performance and reactions, along with vehicle performance simulations, will enable "virtual" testing and training.
<u>Industrial Design</u>: Advanced three-dimensional models and simulations will foster new vehicle design concepts, container designs, terminal management approaches, and traffic management to promote intermodal operations and facilitate transfers between the modal elements of the transportation system.	DOT will need advanced planning and policy formulation, simulation, and modeling tools to represent intermodal interactions well. Increasing pressure for DOT to take a role in the standardization of containers, data exchange formats, etc., to facilitate intermodal trade. More sophisticated and faster screening techniques will be needed to monitor system security while increasing passenger and freight throughput. DOT will have to maintain a workforce which is technically qualified over a broader range of management and technical disciplines.

Table II-1-1. General Technology Trends, Impacts on DOT

CHAPTER 2

STRATEGIC GOALS AND THE ROLE OF RESEARCH

II.2.a. National Goals for Transportation

Considering the likely 2020 future, the NSTC Committee on Transportation R&D has defined a set of strategic goals and measures that encompass safety, security, environmental quality, energy efficiency, economic productivity, accessibility, and mobility. Investment in transportation research, technology, and education can significantly improve the probability of attaining these goals. These goals, summarized above in Table I-1, are discussed at greater length below.

The White House and Federal agencies, in conjunction with the National Research Council (NRC), have been working to identify strategic goals and appropriate measures to determine the impact of Government research and technology investments on the performance of the national transportation system. For example, over the past two years the NRC has conducted roundtables for key members of the Federal transportation enterprise and supported the definition of National transportation goals and strategic partnerships and measures.

What follows is a more detailed discussion of the five major transportation goals upon which both the NSTC *Transportation Science and Technology Strategy* and this plan are based. Potential measures of success and program performance are discussed below in Chapter 6.

II.2.a.i. Transportation Safety

A core transportation objective is to reduce deaths and injuries and to minimize the dangers associated with all modes of transportation. Worldwide, 250,000 people a year are killed in transportation accidents and over 10 million injured. The fatality and injury rates in developing countries are 3 to 4 times those of the U.S. As the number of motor vehicles in the developing world increases, world fatalities may reach 1 million per year, with 40 to 50 million injuries. Another consequence of growing demand will be a doubling of the world civil aviation fleet. At current accident rates, a doubling of civil aviation traffic implies more than 4,500 annual aviation-related fatalities worldwide by 2025.

Today, more than 40,000 people are killed on our Nation's highways each year—the equivalent of a DC-9 crashing and killing all of its occupants every day of the year. Many fatalities are caused by errors in driver judgement due to inadequate or untimely information necessary to avoid a collision. Human error is the most pervasive fundamental problem and the greatest limitation to improving transportation safety and efficiency. Thus, a major focus of the transportation enterprise's R&D activity is to understand the causes of, and determine the means to eliminate, human error as it relates to the safe operation of vehicles in all modes of transportation. Increasingly, transportation is experiencing a paradigm shift toward active accident prevention as a vital complement to passive prevention measures (e.g., highway design) and occupant protection.

Although these activities are directed at the most important root cause of accidents, it would be unrealistic to expect that they could prevent all accidents. Research in the areas of fault tolerance and crashworthiness have been important to reducing the damage caused by accidents that do occur, and a continued commitment to these activities will be of vital importance now and in the future. For example, NHTSA is currently initiating research activities to improve the characterization of new structural materials that may be used in next-generation vehicles, which will help to ensure the proper design of applicable safety standards. FRA and FTA have nearly completed a five-year plan for a joint Commuter Rail Safety Research Program, which would address the following key safety elements: structural integrity and passenger protection; suspension system performance; wheels and other components; signal systems and train control; grade crossing hazards; human factors; fire safety; and emergency preparedness.

These and other major issues ensure that safety concerns will continue to be integral to many transportation R&D initiatives.

II.2.a.ii. Transportation Security

Security is a key element in retaining the public's trust and confidence in the global transportation system. Yet, in the last few decades, the threat of hijacking and deliberate sabotage has become real and highly visible worldwide. In the aviation arena, for example, it is an enormous challenge to keep all weapons and explosive materials off an airplane carrying several hundred people and their highly varied luggage. At the same time, recent plots or actual attacks have been made against railroad, mass transit, and highway targets, both domestically and internationally.

The security of transportation’s information infrastructure is another area of growing concern. A transportation system permeated with information technologies could prove highly vulnerable to malicious and terrorist attacks focused on introduction of false information into the system or interference with computer and communication system operation. As transportation systems become increasingly integrated with information systems, the potential increases for widespread system disruption and personal injury as a result of such security breaches.

II.2.a.iii. Environmental Quality and Energy Efficiency

Environmental and energy concerns affect transportation system development worldwide. Everywhere, transportation is becoming the focus of concerns about fossil fuel consumption, global warming, and air quality. For instance, current scenarios estimate that the world demand for petroleum, by far the primary fuel source for transportation, could double to as much as 150 million barrels per day. Critical fuel supplies to a nation could be disrupted over the short or long term by local conflicts, natural disasters, economic downturns, or conscious political decisions.

As cities grow and the demand for transportation increases, the resulting growth in transportation activity places nearly unsustainable pressure on land use, traffic congestion, and air and water quality. The emissions caused by petroleum consumption contribute to both human health problems and the possibility of global climate change. Although very important progress has been made in reducing emission rates over the past 25 years through the application of technologies such as 3-way catalytic converters and closed-loop fuel control systems, cars, trucks, and other vehicles are still major sources of carbon monoxide, volatile organic compounds, nitrogen oxides, and fine particulate matter. Highways have been blamed for erosive and contaminated runoff and ruination of wetlands. At the same time, communities have formed coalitions that vigorously protest the risks of hazardous materials transport, such as oil spills, and the adverse impacts of transportation noise.

Combined with the dramatic forecasts for growth in world population and transportation demand, these issues have given environmental and energy concerns prominence on the national agenda at the same time that physical and financial constraints are limiting expansion of existing transportation infrastructure to meet demand. Potential strategies to reduce travel demand face tremendous challenges, and it is increasingly apparent that intelligent management and operation of transportation systems will be critical to meeting these wide-ranging and often conflicting demands.

II.2.a.iv. Economic Growth and Productivity

Trade and tourism are areas of great significance to the world's economy. Tourism alone may be the single biggest economic activity in the world today, accounting for over one-tenth of the total global gross product. And, as population and disposable income both grow, a dramatic increase in international passenger travel can be anticipated. In particular, this trend will stimulate growth in air travel, and thus the need for user-preferred routes and schedules, new and expanded airport facilities, and associated transportation connections throughout the world.

Such growth also will stimulate the demand for finished goods, which in turn will expand growth in freight transportation services worldwide. Oceanborne trade is expected to increase at an average rate of 4.5 percent between 1994 and 2005. Just-in-time goods movement—with the goal of minimum inventories—is increasing both the number of trips made by parts suppliers and final assemblers' deliveries to purchasers, creating the need for more efficient and reliable freight movement through urban and suburban centers. At the same time, the shift of manufacturing to the developing world and the increasing "out-sourcing" of component and parts production will necessitate increased freight movements during the manufacturing process itself.

Transportation decision makers at all levels will need to respond rapidly to these demands for passenger and freight services. Yet, many local officials are not aware of the significance of these issues to their regions' economies or of the infrastructure and operational needs of these activities. If they are to consider the entire transportation system—including all modes and the connections among them, both locally and internationally—as well as alternatives to physical travel in making major transportation decisions, transportation officials will need better planning tools, information, and technologies to assess the impacts of such choices.

With today's highly competitive surface transportation enterprise and research, it would be very easy for the U.S. to become a Nation of technology importers and purchasers, rather than innovators and sellers. Both the *Transportation Science and Technology Strategy* and this *Surface Transportation Research and Development Plan*, consistent with the intent of ISTEA, emphasize opportunities for cooperation with industry and "strengthening the manufacturing capabilities of United States firms in order to produce products for surface transportation systems."

While looking toward long-term gains and technological advances, it is also critical to ensure continued attention to incrementally evolving customer needs and deployment opportunities. Established infrastructure and systems are such that applied research represents the majority of research needed to meet ongoing repair and restoration needs.

II.2.a.v. Accessibility and Mobility

The recent major growth in suburb-to-suburb commutes and "reverse" commuting (city center to suburb), new and decentralized employment locations, variable employment schedules, and the growing number of non-commute trips, particularly for women, create considerable challenges for fixed-route transit services and other alternatives to private automobile travel. The challenge for the transportation enterprise will be to manage limited resources effectively to provide access and mobility for all segments of the population.

Among the transportation enterprise's primary missions is to help local agencies provide essential, affordable transportation services to those who—because of age, disability, income, or personal preference—do not use an automobile. For example, estimates suggest that by the year 2020, one out of six members of the population will be over 65, with the fastest growing cohort those least likely to have easy access to automobile transportation—the population 85 and older. Likewise, children, as well as those of any age with physical disabilities have considerable mobility needs. Welfare reform places renewed emphasis on the importance of mobility for those attempting to access and retain employment but do not own an automobile. The spatial disparity of where new employment centers are located and where many of the poor live points to a serious mobility gap.

As is discussed in *II.1.b*, information technology will be an important factor in the evolution of future travel patterns, and will also play a critical role in the management and operation of transportation systems to meet future mobility requirements.

II.2.b. The Role of Research

The goals described above present the entire transportation enterprise with a challenge of great magnitude, particularly in a time of financial constraints, growing demand, and decentralization and devolution of transportation responsibilities. From the DOT perspective, there is an additional imperative to find more effective and less costly means of carrying out Federal operational and regulatory responsibilities. Research, and the innovation that it enables, will be a critical component in the National response to this challenge. The stimulation and fostering of innovative technologies and methods in transportation will thus be central to meeting national needs in the next century.

Fortunately, these challenges, and the associated necessity for continuing innovation, arise in an era richly endowed with a wide range of steadily-advancing technologies and tools that, effectively applied, have great promise for resolving current or anticipated problems. Innovation is seldom a smooth process, and realization of significant change in transportation systems–tightly linked to their environment and characterized by very long-lived infrastructure and vehicles–is complex and difficult. Research and development enables and stimulates innovation by the three both parallel and interconnected paths which are described below.

II.2.b.i. Development of New Technologies

Various modes of transportation have at times been revolutionized by the development of practical realizations of new technologies, such as the diesel locomotive and the jet engine. Major research efforts are currently under way to improve the fuel efficiency of personal motor vehicles and provide propulsion based on non-petroleum sources, such as electricity or alternative fuels, perhaps using advanced energy conversion technologies such as fuel cells. While rare, innovations yielding a quantum leap in economic efficiency, speed, or safety can transform the operations and role of affected transportation functions or modes, and dramatically change the performance of the entire system. New technologies may be essential to the solution of problems that would otherwise be intractable.

II.2.b.ii. Introduction of Existing Technologies into Transportation

The most common way in which R&D affects transportation lies in fostering and facilitating the adoption of technological advances in many fields into transportation applications. The use of information technology throughout the transportation enterprise is a particularly prominent current example, accompanied by application of improved materials in physical infrastructure as well as vehicles, nondestructive testing and inspection techniques, computer-aided design, and environmental engineering. Such technology is enabling the necessary transition from an emphasis on building new physical infrastructure to meet transportation demand to an emphasis on effectively managing transportation systems to improve operational efficiency.

The introduction of innovative technologies itself raises many questions and challenges, including not only technical considerations but also uncertainties as to cost, effectiveness, and unintended consequences. Specific focused research initiatives are often essential to rapid and effective integration of available technologies in transportation functions.

II.2.b.iii. Increased Knowledge for Decisions and Actions

Whether innovation derives from new or existing technologies and operational concepts, a broad foundation of data, knowledge and understanding–concerning both transportation and the relevant technologies–is required for diagnosis of perceived transportation problems, identification of potential solutions or opportunities, comprehensive characterization and evaluation of alternatives (including their interaction with the people who use and operate them), and development of effective deployment strategies. Understanding of the interactions between humans and transportation systems, whether as users, operators or designers, is far from complete.

Transportation policies and decisions, whether public or private, must address a steadily widening range of considerations. Many stakeholders are involved, and the technical realities and uncertainties are generally complex. National policies can place heavy burdens on state and local agencies for planning and decision making in technically complicated areas. An example of ongoing research to ease this burden is the development of the sketch planning tool known as the ITS Deployment Assessment System. Without such tools and other needed information and data, it would be very difficult to meet these challenges.

II.2.c. Federal Involvement in Research and Development

The essence of Federal involvement in R&D was concisely stated in a 1995 report of the President's Council of Economic Advisors: "First, successful R&D in private companies depends on the flow of new ideas and trained people stemming from basic research and pre-commercial R&D. Federal support of these activities is vital. Second, the Federal government sponsors much applied research to improve its own capabilities in such areas as National security, health, and transportation." The nonprofit, nonpartisan Council on Competitiveness echoed this theme: "The Federal government must meet its long-standing obligation to stimulate civilian research."

With respect to transportation, this obligation takes the form of Federal research and technology initiatives, increasingly conducted in partnership with the private sector and academia, to stimulate innovation across the transportation enterprise. Although development of advanced transportation technology and improved operations is largely the responsibility of the private sector, focused federal investment in research, development, test, evaluation, and technology dissemination can have great impact in the many areas in which market-driven R&D efforts are impeded by technological and other uncertainties as well as strong institutional impediments. The basic criteria applied are that the research must support long-term National goals, but with benefits too widespread, uncertain or distant to motivate private sector firms to invest independently. In addition, the largely non-Federal nature of the transportation sector mandates that R&D be conducted in collaboration with the firms who will ultimately design and manufacture products for the marketplace, the organizations that will operate and maintain the resulting systems, and the shippers and passengers who will use them.

Federal R&D is also called for where it is necessary to support the efficient performance of agency mission responsibilities, such as operation of federally-provided transportation-related services, guiding of public investment in the transportation system, and regulation of transportation safety and security.

II.2.d. National Transportation Science and Technology Strategy

Careful planning is essential for managing and leveraging limited Federal research, development, and education and training resources to meet 21st century transportation challenges and opportunities.

The NSTC Coordinating Committee on Transportation R&D (CTRD) was created in 1994 to ensure that the Federal investment in transportation R&D is (1) coordinated to ensure efficient use of Federal funds aimed at this mission; (2) focused on projects identified by users, industry, and other stakeholders as being the most critical to achieving success in agencies' missions; and (3) limited to areas where it is clear that major public benefits can only be achieved through cost-shared Federal research.

Through its initial planning efforts—with major involvement of the transportation community—
the Committee has completed the first *Transportation Science and Technology Strategy* to help Congress, the White House, and Federal agency heads to establish National transportation R&D priorities and coordinated research activities. The Strategy is based on the results of numerous outreach events, environmental scans, and an analysis of the transportation system's current and future strengths, weaknesses, opportunities, and threats. The Strategy provides a framework for National partnership initiatives, enabling research, and education and training necessary to achieve National transportation goals. The vision, goals and conceptual approach that underlie the Strategy are presented in Section I of this plan, which highlights those elements that focus on the surface transportation system. As described in Section I.c, the Strategy has four components: (1) Strategic Planning and Assessment; (2) Strategic Partnership Initiatives; (3) Enabling Research; and (4) Transportation Education and Training.

II.2.d.i. Strategic Planning And Assessment

The institutionalization of a continuing transportation R&D strategic planning and assessment process will enable policy makers and implementers to adjust the allocation of scarce national R&D and other resources to meet changing requirements. This ongoing process, involving the establishment of a broad consensus among all levels of government, industry, and academia, will (1) establish and assess transportation goals in accord with a changing external environment; (2) identify strategic technology partnerships to support transportation goals; (3) identify a long-term enabling research agenda to support future transportation goals; and (4) develop measures of progress against national goals to evaluate the impact of Federal R&D investments. Outreach to leaders in industry, state and local government, academia, the research community, and other stakeholders has allowed the Federal Government to gather facts and analyze trends that give an objective picture of where we stand in the transportation "world," and of the external and internal pressures and factors likely to affect our future.

As observed during the March 1995 TRB/NSTC Forum on Future Directions in Transportation R&D, technological integration is needed at all levels to rectify current inadequacies in the following areas:

> *System Assessment*--There is a need for improved data, analyses, and assessments in all aspects of transportation system performance.
>
> *Policy Research*--Although technology is also important in systems assessment, there are critical issues that are more institutional or policy oriented than technical.
>
> *Intermodal Research*--Advances in the characterization and modeling of system operations will be required in order to take full advantage of the opportunities to improve system efficiencies through effective use of all modes.

As is discussed in detail in Chapter 6 of this section, this ongoing activity necessary for effective management of all subsequent components of the Strategy must be supported by effective performance measurement. Through its current interagency strategic planning processes, the Department is currently vigorously pursuing the identification of a wide range of performance measures that address the transportation system as a whole, specific transportation modes, progress toward ultimate societal goals, and the success of individual programs.

II.2.d.ii. Strategic Partnership Initiatives

The Strategy specifically proposes a set of 12 research initiatives to be pursued as partnerships among government, industry, and academia. Particularly in transportation, which is a very applied discipline, investments in basic science and research are often best undertaken in collaboration and the exchange of people and ideas among Federal agencies, state and local governments, private companies, universities, public interest groups, and other stakeholders. Strategic partnerships can be an effective means to expedite the research process and speed the introduction of valuable innovations into transportation systems and operations. These initiatives do not address the entire body of research needed to ensure desired improvements in transportation, or to meet all basic DOT responsibilities. They represent unique opportunities for leveraging of scarce resources to achieve rapid gains in specific technical areas.

The twelve partnership initiatives are listed below and presented in detail in Chapter 3 of this section. The initiatives fall into three categories: (1) transportation information infrastructure; (2) next-generation vehicles; and (3) transportation physical infrastructure.

- *Transportation Information Infrastructure*

  Smart Vehicles and Operators
  National Intelligent Transportation Infrastructure
  Next-Generation Global Air Transportation
  Enhanced Transportation Weather Services
  Enhanced Goods and Freight Movement at Domestic and Int'l Gateways
  Accessibility for Aging and Transportation-Disadvantaged Populations
  Local Environmental Assessment Systems

- *Next-Generation Vehicles*

  Next-Generation Motor Vehicles and Ships
  Aviation Safety Research Alliance

- *Transportation Physical Infrastructure*

  Total Terminal Security
  Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure
  Environmental Sustainability of Transportation Systems

II.2.d.iii. Enabling Research

Transportation inherently is based upon the application of a wide range of scientific and engineering disciplines, some of which are specific to transportation, and some of which have broader applicability. Innovation in transportation therefore necessitates ongoing R&D focused on adaptation of more-generic technologies examination of aspects unique to transport functions. The societal benefits of innovation can often be widely dispersed or require a long time period for realization. Hence, economic, institutional and other constraints make research of this type unattractive for private investment. In these areas, Federal R&D is warranted, accomplished wherever possible in multi-agency collaborations. The NSTC Transportation S&T Strategy identifies six areas of long-term enabling research that are appropriate and promising in terms of their potential contributions to transportation innovations. These are listed below and discussed in detail in Chapter 4 of this section.

- Human Performance and Behavior
- Advanced Materials
- Computer, Information, and Communication Systems
- Energy Conversion for Propulsion
- Sensing and Measurement

II.2.d.iv. Transportation Education and Training

The benefits from national investments in transportation, whether based on existing or innovative technologies, are dependent on the transportation professionals and workers responsible for the design, construction, operation, and maintenance of the overall system. In the case of new technologies or novel applications, it becomes all the more important to assure that an appropriately trained workforce, with sophisticated technical knowledge and a strong understanding of the societal context within which transportation functions. This area is not new to the Federal government, which has a long history of supporting education. Current DOT activities include the University Transportation Centers Program, the Eisenhower Fellowships, the Aviation Education Program, and the National Highway and National Transit Institutes. Transportation today is undergoing great change—experiencing advances in technology, undergoing organizational transformation, and continuing globalization along with the world economy. These changes require that the Department and partner agencies expand efforts that will enable current and future generations of transportation professionals and workers to meet the demands of the 21st century. The three focal points of support for education and training investment are noted below and discussed at length in Chapter 5 of this section.

- Introduction of Transportation Concepts: Elementary and Secondary Education
- Vocational and Technical Training
- Transportation Degree Programs: International and Multi-disciplinary
- Mid-Career Transportation Training

II.2.e. The R&D Role of the Department of Transportation

Innovation in transportation calls for a balanced and integrated approach that links parallel streams of research, development, test and demonstration, and implementation. This entire process must be based on a clear understanding of specific transportation objectives and institutional, regulatory, and economic constraints. The translation of a tested and proven advance into revenue service or operational improvements often necessitates a major investment in providing users with sufficiently convincing evidence of its performance and probably benefits and with the knowledge needed to apply the innovation effectively.

The Department sponsors a range of research and development activity to support fulfillment of its core responsibilities, which are as follows:

- Establishing standards for safety and other key aspects of the transportation system, facilitating deployment of safe and effective transportation equipment and systems.

- Distributing funds to state agencies, transportation providers, and other related institutions to plan, construct, and operate the transportation system.

- Interacting with other Federal agencies to carry out broader Federal mandates such as the Clean Air Act and National security policies.

- Providing law enforcement and traffic management systems for the Nation's airspace and waterways.

R&D is critical to the Department's ability to meet the multiple, and sometimes conflicting demands the Nation places on its transportation system, particularly in an era of scarce resources. As the national steward of the transportation system, the Department has a unique responsibility to work in partnerships with state agencies, transportation providers, and other related institutions to ensure that the Nation fully capitalizes on technological, operational, and institutional innovations.

CHAPTER 3

PRIORITY STRATEGIC PARTNERSHIPS

A wide range of transportation R&D is needed to support basic DOT responsibilities, such as the establishment and enforcement of safety regulations. Strategic plans for this research are established by each of the Department's operating administrations, which collaborate on an interagency basis through the Department's Research and Technology Coordinating Council, and with stakeholders through a range of processes, and participate jointly in the development of departmentwide strategic planning documents such as this *Surface Transportation Research and Development Plan*.

Improvement is highly desirable in many aspects of transportation, and interesting and attractive innovative technological and operational concepts abound. Without an ongoing commitment to transportation research and development, the Nation would risk a high level of importation of key technologies. It has been estimated that the global ITS market for surface transportation will be in the hundreds of billions of dollars by 2025. However, it is clear that Federal government research over the next ten years, both that addressing basic governmental responsibilities, and that designed to take advantage of new opportunities for improvement, must be conducted in a climate of severe fiscal restraint. Ongoing consideration of the broad transportation R&D context will be essential, and will encompass important activities throughout the Federal Government, academia, the States, and industry.

The second tier of the NSTC Science and Technology Strategy, and one of its critical elements, is the identification of research partnerships among government, industry, and academia. One of the tenets of the President's Committee of Advisors on Science and Technology is that the Nation can best profit from investments in basic science and research through partnerships and the exchange of people and ideas among Federal agencies, state and local governments, private companies, universities, public interest groups, and other stakeholders. For agencies with transportation R&D responsibilities, strategic partnerships can expedite the research process and speed the introduction of much-needed new technologies into transportation systems and operations. Based on broad public and private sector input, this Strategy identifies twelve partnership initiatives, ten of which address surface transportation, offering some of the greatest benefits for transportation. Chapter 6 of this Section addresses the importance of an ongoing process to measure the performance and benefits of these initiatives and the whole of transportation R&D, and to integrate this into an ongoing strategic planning process.

All of these initiatives build on recommendations from various outreach events and meet all of the criteria listed to the right. The role of the Federal government in planning the details of these initiatives, and in implementing those plans, will vary depending upon the nature of the initiative and the range of partners.

> **Criteria for Partnership Initiatives**
>
> - Addresses a real recognized need.
> - Has a technology focus--ideally a self-contained, readily implemented piece of technology.
> - Market for the technology-based improvement exists--if successful with the technology, could rely on existing market forces and the private sector for widespread implementation.
> - Is a need for a Federal role, with benefits to the Nation as a whole--taxpayers, traveling public, industry; the initiative could not proceed in a timely fashion without Federal involvement, support, or coordination, but also requires private sector cooperation and participation.

These initiatives do not cover the full scope of the Nation's long-term surface transportation needs and, in particular, do not address the full range of DOT responsibilities. They are not intended to do so. However, they will help to make important and visible progress toward the long-term the National goals for transportation identified above in Chapter 2, and reflect prioritization of activities and resources in an era of limited resources.
The initiatives fall into three overlapping and interrelated categories: (1) transportation information infrastructure; (2) next-generation vehicles, and (3) transportation physical infrastructure.

- *Transportation Information Infrastructure*

  Initiative #1: Smart Vehicle and Operators

  Initiative #2: National Intelligent Transportation Infrastructure

  Initiative #3: Next-Generation Global Air Transportation

  Initiative #4: Enhanced Transportation Weather Services

  Initiative #5: Enhanced Goods and Freight Movement at Domestic and International Gateways

  Initiative #6: Accessibility for Aging and Transportation-Disadvantaged Populations

  Initiative #7: Local Environmental Assessment Systems

- *Next-Generation Vehicles*

  Initiative #8: Next-Generation Motor Vehicles and Ships

  Initiative #9: Aviation Safety Research Alliance

- *Transportation Physical Infrastructure*

  Initiative #10: Total Terminal Security

  Initiative #11: Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure

  Initiative #12: Environmental Sustainability of Transportation Systems

II.3.a. Transportation Information Infrastructure

II.3.a.i. Smart Vehicles and Operators

> **Initiative:** Smart Vehicles and Operators.
>
> **Goal:** Reduce the occurrence of accidents in all modes of transportation through an enhanced understanding of human performance and behavior; the application of human-centered technological aids and systems for accident avoidance; and the development of advanced materials and technologies for vehicle operator training.
>
> **Participants:** DOT (FHWA, NHTSA, FAA, FTA, FRA, USCG, MARAD), DOC, and other Federal agencies; the technology community; vendors; states; associations of vehicle operators; transportation companies; and vehicle manufacturers.
>
> **Benefits:** A safer highway, railroad, transit, and waterways system, with fewer deaths, injuries, suffering, and property loss, accompanied by a reduction in trauma injuries for the U.S. health care system; reduced transportation vehicle repair costs; and, potentially, reduced automobile insurance premiums.

The first priority in safety is prevention—stopping accidents before they occur. The great majority of transportation accidents involve at least some degree of operator error brought on by fatigue, inattention, or incapacitation. An appropriate response to these concerns can be formulated only on the foundation of a solid understanding of human characteristics as they relate to vehicle operation.

Technical advances, particularly in information technologies, now offer many possibilities in terms of devices to warn operators of unsafe circumstances, or to suggest or even initiate corrective actions. The ITS program, for example, specifically includes elements intended to assure full exploitation of these opportunities. Additionally, innovative means of inspecting and monitoring the condition of vehicle and infrastructure components, periodically or while in operation, can make it possible to take corrective action before an accident occurs.

This partnership initiative incorporates a wide variety of R&D activities associated with accident avoidance. For conciseness, they are discussed here in three broad groups: human performance, accident avoidance technologies, and operator training and education.

> *Human Performance*: Research directed toward better understanding of operator performance in transportation systems now offers great promise. As these results are incorporated in vehicles, infrastructure, and overall system design and operation, and accompanied by new technological aids to provide information and alerts to operators, dramatic safety benefits will result. Among other activities, this initiative will support the development of new simulator capabilities, such as those now being completed for motor vehicle operator research, that will add substantially to our understanding of operator behavior and decision making and assist in the evaluation of the human–machine interface.

> *Accident Avoidance Technologies*: An important use of advanced information technology in transportation is the deployment of devices to improve operator awareness, warn operators of hazardous circumstances or imminent threats, or initiate responses to hazards. The ITS program, for example, includes a substantial component that seeks to exploit these possibilities through vehicle–wayside communications, whether by on-board devices or variable message signing. This proposed initiative will assess the potential of an additional category of opportunities for preventing accidents—vehicle-based systems, such as Positive Train Control. Other such systems include "smart ships," vessel tracking systems, air traffic alert and collision avoidance systems, synthetic vision (e.g., night vision aids), smart cruise control, collision warnings or automated braking, devices to detect vehicles in "blind spots," and sensors to detect that operator alertness has dropped to a hazardous level.

> *Training and Education*: Even with a greatly improved understanding of human performance and a set of advanced collision-avoidance technologies that draw upon that knowledge, training and education will continue to be vital to ensure that vehicle operators are knowledgeable about safety systems and safe operational procedures for the vehicles they operate. This initiative will support the development of interactive

programs (e.g., CD-ROM video games, simulators) to train and evaluate vehicle operators under a wider range of operational scenarios than is currently possible.

II.3.a.ii. National Intelligent Transportation Infrastructure

Over the last decade, traffic in metropolitan areas has increased at a far faster rate than available road capacity. The daily vehicle- miles of travel per lane of urban highway has grown by nearly 30 percent, and this has led directly to greater congestion, energy use, air quality problems, and sprawl. During the past 15 years, both the number of trips per person and the miles per trip have increased at about 3 times the rate of population growth. Vehicle-miles traveled in urban areas have been growing at about 4 percent a year. In the face of this explosive growth in travel, the transportation system's capacity has not kept pace. DOT estimates that to just equal the growth in vehicle-miles traveled, the U.S. transportation system would need to build approximately 35 percent more highway capacity. Doing so for 50 of our most congested metropolitan areas—for which the total cost of congestion is $43 billion a year— would cost about $150 billion.

Initiative: National Intelligent Transportation Infrastructure.

Goal: Deploy an intelligent transportation infrastructure across the United States within the next decade.

Participants: DOT (FHWA, FTA, FRA, NHTSA); State DOTs; MPOs; emergency response and law enforcement agencies; private industry.

Benefits: Reduction in travel times in metropolitan areas; faster life-saving emergency response and fewer congestion-related traffic incidents; more efficient public services; reduced petroleum consumption; improved air quality; increased infrastructure capacity without costly new construction; enhanced information system security.

Congestion also has an impact on commercial motor vehicle travel, particularly when coupled with the administrative burden associated with regulatory compliance. Motor carriers are legally required to obtain numerous and information-intensive credentials and clearances for interstate operations. On the average, interstate carriers may deal with five or six public agencies within each of the states in which they operate. Regulatory compliance not only creates administrative inefficiencies and redundancies, but it increases labor costs. Total compliance costs for the industry are estimated to be as high as $5 billion a year. The costs to the public sector are even greater, due to the volume of paperwork associated with motor carrier inspections, credentialing, and tax collection.

Rural transportation poses yet another set of challenges. The transportation needs of rural areas differ significantly from those of cities. Although less than 40 percent of annual vehicle-miles traveled are on rural roads, these roads account for 60 percent of all traffic fatalities because of higher speeds and relatively slow emergency response. Many rural residents are isolated, without a car or access to public transportation. Thirty-eight percent of rural residents live in areas without any transit services; another 28 percent live where the level of service is negligible. Moreover, visitors to rural tourist areas have limited access to directions and to other basic travel information.

Intelligent transportation systems, or ITS, offer promising solutions that respond to these pressing challenges in urban, commercial, and rural surface transportation. These systems are diverse and versatile, combining telecommunications, computer, sensing, and electronics technologies to provide real-time information to traffic managers and travelers on traffic, weather, navigation, and vehicle diagnostics—in much the same way that the air traffic control system does for air traffic—to achieve greater system efficiency, safety, and convenience.

In partnership with state and local agencies and industry, this partnership initiative will support the creation of a national intelligent transportation infrastructure—a transportation communications and information backbone—that will help to ensure that the various ITS strategies being deployed across the country are integrated, interoperable, intermodal, and secure. This national infrastructure comprises three broad systems:

> *Metropolitan ITS Infrastructure*: This infrastructure will integrate advanced traffic management, traveler information, and public transportation systems to meet the needs of metropolitan areas.
>
> *Commercial Vehicle Information Systems and Networks*: This will integrate data, technology, and communications systems to make safety regulation of commercial vehicles faster and more effective, and to make compliance transactions more efficient for both motor carriers and regulators.
>
> *Rural ITS Infrastructure*: This infrastructure will upgrade communications and information technologies in rural communities and link rural areas to the metropolitan information infrastructure.

Through this initiative, Federal agencies will work with industry and state and local partners to deploy various elements of this overall infrastructure. The Federal role will include providing incentives for deployment, supporting public–private model deployments and technology demonstrations, developing innovative financing and acquisition processes, promoting the acceptance of national standards, providing training and technical assistance, and pursuing focused research and development. A major component of this effort will address the security concerns arising from opening new avenues of communication among transportation agencies, emergency services, other agencies, and the traveling public. Together with the increasing dependence on information and communication technologies, this trend has heightened transportation systems' vulnerability to information security problems.

II.a.3.iii. Next-Generation Global Air Transportation

Initiative: Next-Generation Global Air Transportation.

Goal: Enhance aviation system safety, efficiency, and capacity by demonstrating next-generation concepts for air traffic management and validating the associated technologies, procedures, and operational benefits.

Participants: DOT (FAA, Coast Guard); NASA; DOD; airlines; manufacturers.

Benefits: Improved safety and efficiency of the air transportation system in the face of increasing demand in domestic and oceanic airspace; advancement of the state of the art in aviation communications, navigation, surveillance, weather, and decision-support systems; promotion of Government–industry cooperation in critical areas of aviation technology; and improved U.S. balance of trade for aviation technologies and products.

Recent Government–industry partnerships have developed a number of advanced technologies for air traffic management, as well as consensus on operational improvements required for enhancing the safety, flexibility, and efficiency of air traffic management operations. In particular, the "free flight" concept, developed in collaboration with U.S. airspace users, envisions a system wherein aircraft operators have wide latitude for selecting flight paths, speeds, and altitudes that best satisfy their operational requirements; the air traffic management system imposes restrictions only to ensure that aircraft are separated and that other essential safety requirements are met.

Most of the technologies that would foster free flight have been developed and tested on a small scale. The next step in the practical application of these technologies is integration, demonstration, and validation in the operational environment. This activity not only will set the stage for national deployment of the next- generation air traffic management system, but will affirm U.S. leadership in aviation by show-casing the new technologies and promoting global markets for U.S. aviation products.

This initiative will implement and validate advanced air traffic management technologies and procedures under real-world conditions. The activity is essential to FAA and industry efforts to evaluate the consequences of changes in the operational concepts and procedures required to exploit the new technologies. The potential of the new technologies has been successfully demonstrated—on a limited scale for helicopters—at the 1996 summer Olympics in Atlanta.

There, the FAA, in partnership with the Olympic Committee, industry, helicopter operators, and NASA, demonstrated the use of satellite-based navigation and surveillance techniques in managing the large number of passenger, cargo, and security helicopters supporting the games.

The proposed effort would implement and demonstrate the new system in two regions, one each in Alaska and Hawaii. Hawaiian airspace is an ideal location because it is geographically isolated and serviced by a relatively small number of aircraft, making technology upgrades more affordable and manageable. Further, because Hawaii is a popular international destination, it offers a unique opportunity to showcase U.S. technologies for the rapidly growing aviation markets in Asia and elsewhere. Alaska also has the advantage of relative geographic isolation. In addition, it provides challenging weather conditions and terrain that the new system addresses by providing relevant safety information in the cockpit. The demonstration in Alaska therefore will validate the ability of the new technologies to significantly increase the safety of flight operations.

This initiative will exploit and expand existing partnerships among industry, airspace users, the FAA, NASA, and DOD. These collaborations created the concept of free flight, and have been productive in developing and testing the new air traffic management technologies that provide a basis for the next-generation system. Safe Flight 2000 is the essential next step in air traffic management system development.

II.3.a.iv. Enhanced Transportation Weather Services

For the transportation system, the safety, mobility, and economic impacts of adverse weather conditions are considerable. According to a report of the Office of Science and Technology

Initiative: Enhanced Transportation Weather Services.

Goal: Improve transportation safety and efficiency by demonstrating the data-integration capabilities necessary to provide short-term, very small scale weather forecasts.

Participants: DOT (FAA, FHWA, Coast Guard, FRA); NWS; private vendors; state and local agencies.

Benefits: In aviation, improved capabilities for flight planning and severe weather avoidance, greater system throughput, reduced fuel consumption, and lower deicing costs for airports; for ocean shippers, financial savings due to forecasts that allow planning for the most efficient routes; and in surface transportation, reduced highway accidents and related injuries, lower costs for trucking firms, and lower snow- and ice-control costs for state and local highway departments.

Policy (OSTP), each year weather causes or contributes to 6,000 fatalities on U.S. highways and 800 aviation-accident-related deaths. The OSTP estimates that more than half of all flight delays are attributable to weather, and that uncertainties in predicting flight-level winds add a quarter billion dollars annually to the nation's aviation fuel bill. Moreover, the FHWA states that between 25 and 35 percent of all intercity road accidents occur during adverse weather, with the risk of accidents increasing during bad weather by a factor of from 2 to 5.

Advances in weather technologies and meteorology during the past decade offer the promise of mitigating many of the impacts of severe weather on transportation. Among these are new observation systems, such as Doppler radars and Automated Surface Observing Systems; advances in computing speed and capacity; and greater fundamental knowledge of weather systems. In fact, weather observation and information-processing capabilities have expanded so greatly that it is now feasible to combine weather data from many sources into massive databases and manipulate the data with numerical models to produce reliable short-term weather forecasts for individual roads, traffic arteries, bridges, airport runways, air corridors, ports, and waterways. However, the full potential of such small-scale forecasting will not be realized without further improvements in weather data integration and dissemination. Of immediate utility, when available, will be the results of the ongoing research to develop message sets and protocols for the road-weather information system under the National Transportation Communications for ITS Protocol (NTCIP) project.

The benefits of such improvements are already being demonstrated. For example, at Chicago's O'Hare International Airport, the National Center for Atmospheric Research, as part of an FAA initiative, has combined radar and sensor data to provide snowfall predictions for up to 30 minutes for 1-square-kilometer areas of the airport complex. The data integration is accomplished using a high-performance computer workstation. Snowfall forecasts are displayed in graphical form on monitors in the airport and airlines' operations centers. This same capability will be demonstrated at New York's LaGuardia Airport in collaboration with the Port Authority of New York and New Jersey.

Building upon this work and the forecasting capabilities already developed by the NWS, this partnership initiative will provide the planning and underlying infrastructure required to integrate all radar, sensor, and satellite data with local geographical information within a selected state and provide 30-minute, and eventually up to 120-minute, localized statewide weather forecasts.

II.3.a.v. Enhanced Goods and Freight Movement at Domestic and International Gateways

The Nation’s economic success relies on access to worldwide markets for its goods and services. However, as other countries vie for global and U.S. markets, America’s competitive position continues to be challenged. Critical to the Nation’s future competitiveness is the development of an enhanced integrated transportation system for the movement of international and domestic freight, based on advanced infrastructure technologies and more efficient communication and information systems.

> **Initiative:** Enhanced Goods and Freight Movement at Domestic and International Gateways.
>
> **Goal:** Enhance U.S. economic growth by expanding the overall share of global and domestic trade markets through advances in transportation technology and systems.
>
> **Participants:** DOT (MARAD, FRA, FAA, FHWA, NHTSA); DOC; and other organizations representing the public, private, and defense sectors.
>
> **Benefits:** A more productive, competitive national economy and a more flexible, efficient, and seamless U.S. freight transportation system.

It is increasingly accepted that efficiency is improved and costs reduced when international and domestic freight moves along integrated "pipeline" systems from origin to destination, linking various modes as required. Reliance on just-in-time production and inventory management practices has increased the demand for better freight transportation, yet inefficiencies at any point in the pipeline can disrupt the total system—resulting in reduced profits for transportation providers and higher costs for freight shippers and consumers. The goal of freight transportation R&D must therefore be to develop seamless intermodal networks for the entire trip—from origin to destination.

This partnership initiative will develop segments of such a seamless, intermodal freight transportation system. On the water side, this initiative will focus on advanced terminal design and operating systems that complement changing ship designs and operations. On the land side, this effort will incorporate advances in high-speed freight rail networks, truck/container transport and handling systems, truck/airport interface systems, and rail/truck/water interface systems. This will include consideration of revolutionary concepts such as unmanned underground tube freight capsules. Such concepts must be considered from the standpoint of capital and operational cost, as well as compatibility with current freight transport systems--staff at the Volpe National Transportation Systems Center have, for example, recently completed an initial study of such issues for the tube freight concept. Each of the above segments also will require application of communication and information systems technology and infrastructure.

As a public–private partnership, this initiative will dovetail and supplement existing programs that address critical elements of an enhanced, integrated freight transportation system. One such program is the President's shipbuilding revitalization initiative. This program's R&D element, called MARITECH, focuses on advanced commercial ship designs and modernization of shipyard facilities, processes, and procedures. Another element of the President's revitalization plan is the Title XI loan guarantee program, which to date has financed more than $143 million in U.S. shipyard modernization projects.

II.3.a.vi. Accessibility for Aging and Transportation-Disadvantaged Populations

> **Initiative:** Accessibility for Aging and Transportation- Disadvantaged Populations.
>
> **Goal:** Create seamless regional alternative transportation systems serving the needs of the elderly and transportation-disadvantaged while optimizing the existing human and capital investment in paratransit.
>
> **Participants:** DOT (FTA, FRA, FAA, FHWA, NHTSA); HHS; private vendors; and state, regional, and local government agencies.
>
> **Benefits:** Reduced health care costs for the elderly; reduced welfare expenditures and improved job placement and retention for welfare recipients; and reduced public outlays for new equipment through improved management of existing infrastructure and assets.

Although the United States possesses one of the safest and most extensive passenger transportation systems in the world, the system is unable to provide optimal mobility for selected and growing portions of the population. These segments include the elderly, the physically challenged, and the poor:

- Today, 12 percent of the population is 65 or older. Estimates suggest that by the year 2020, up to 20 percent of the population will be over 65, and the fastest growing cohort will be those least likely to have easy access to automobile transportation—those 85 and older.

- Those young or old with physical disabilities have considerable mobility needs. Transportation to medical facilities, schools, training centers, and workplaces are critical to their health and well-being.

- The transportation needs of the poor, particularly inner-city and rural populations, have been an important priority in national transportation and human service policies. However, recent welfare reform legislation requiring states to implement welfare-to-work programs places renewed emphasis on the importance of mobility for those attempting to access and retain employment.

Even for those with access to automobiles, mobility is not assured. In many urban areas, road congestion extracts a high cost in delay, irritation, safety, energy use, and adverse environmental impacts. Yet, demand for transportation services continues to increase. Most areas in the U.S. where such congestion is a problem can no longer respond by simply building more physical infrastructure. The answer necessarily lies in innovations that permit more effective and efficient use of the existing system, with greater intermodalism and seamlessness among the varied system elements.

Government investment in paratransit has provided the vast majority of the transportation options available to these populations. Paratransit is typically defined as flexible-route, low- or medium-capacity vehicles serving a predetermined group of people, such as the elderly, for a fee. The need for these services is growing. Demand-responsive paratransit nationwide has doubled the number miles traveled over the last 10 years to nearly 600 million miles per year.

Although paratransit fills an important transportation gap for many parts of the population, its financial viability has been underwritten with substantial government funding—Federal, state, local, and private—rather than from its own revenues. High operating costs and poor management strategies that do not optimize the use of drivers and vehicles have made such services costly and less than fully responsive to their riders' mobility needs.

This partnership initiative will improve the regional mobility of the elderly and transportation-disadvantaged through better management of paratransit operations and assets. This will be achieved by developing, deploying, and testing a program that will utilize selected information system technologies and applications, including automatic vehicle location, state-of-the-art vehicle communications, geographical information systems, computer-aided dispatch, and electronic fare collection. These technologies will be integrated into a centralized regional control system to manage otherwise independent paratransit operators. Centralized dispatch, monitoring, and fare collection for regional paratransit services provided by transit properties, Councils on Aging, and human service providers within a single region will be conducted from a regional mobility management center.

Although a number of "smart" technologies are currently being used or individually demonstrated throughout the country, no single regional testbed exists that attempts to manage all paratransit services within a region. The power and reduced cost of commercial off-the-shelf information, communication, and navigation systems makes possible the deployment of a regional access and mobility program.

II.3.a.vii. Local Environmental Assessment Systems

Assessment of environmental impacts, and of the cost-effectiveness of countermeasures, is in most cases a very difficult process. For example, urban air pollution depends in part on vehicle emission characteristics, patterns of travel, weather and climate conditions, and very complex atmospheric chemistry and physics. Moreover, it is often not possible to predict accurately the travel behavior changes that may be associated with a particular air-quality change, whether involving road construction, traffic control, or demand management.

> **Initiative**: Local Environmental Assessment Systems.
>
> **Goal**: Further develop data, validated models, and a comprehensive knowledge base to support analysis of transportation-related environmental impacts and alternative strategies, including use of "virtual travel," by all levels of government and the private sector.
>
> **Participants**: DOT, EPA , other responsible Federal agencies, state and local environmental authorities, National Laboratories, the private sector, academia.
>
> **Benefits**: Improved ability of government agencies to respond strategically to environmental objectives and to characterize the transportation implications of those objectives.

As a result, many uncertainties surround the environmental aspects of major transportation investment and regulatory decisions. This can be an especially serious problem for local government planning bodies, which often lack the sophisticated tools and technical staff needed to deal with such complex issues. Significant new opportunities, including new operational practices made possible by dramatic improvements in information technology, are being made available to MPOs and local agencies. However, in order to understand the possibilities and make effective choices, these organizations require models capable of predicting the range of impacts of such practices.

Problems also can arise in the degree to which environmental regulatory agencies appreciate the transportation impacts of their decisions. Since the consequences for transportation system performance, public health, and overall quality of life can be severe, it is critical that the Federal Government conduct a wide range of research activities focused on clarifying all aspects of major transportation-related environmental issues. The recently proposed tightening of U.S. standards for ambient concentrations of ozone and fine particulate matter, for example, would likely expand the geographic scope of non-attainment and create the need for additional measures to reduce transportation sector emissions. This topic also has a large international component. International agreements to limit emissions of carbon dioxide and other gases could have profound consequences for domestic transportation.

Another need that this initiative will address is for an increased understanding of the relationship between transportation and land use decisions. This effort will support the development of analytical tools that MPOs and other transportation decisionmakers can use to assess the implications of transportation projects for overall sustainability, including land use, economic development, and accessibility.

The development of such tools is the primary objective of FHWA's Highway Planning research program, discussed below in Section III, Chapter 6. Priorities of this program include the development of sketch planning tools for assessing ITS deployment options; the development of innovative data collection methods; and implementation of the Travel Model Improvement Program (TMIP) and TRansportation ANalysis SIMulation System (TRANSIMS) program.

This partnership initiative will develop data and analytical models to provide a comprehensive environmental knowledge base to support decisions, policy formulation, and transportation investments in all modes. It will expand and build upon the work conducted under the TMIP, an interagency effort aimed at developing a new generation of travel demand models. The TMIP includes both research to enhance current modeling practice and a longer term initiative to develop a new approach using the latest advances in computing technology (known as TRANSIMS). This new approach uses microsimulation to depict travel patterns and couple them with a modal emissions model, allowing Metropolitan Planning Organizations (MPOs) and other agencies to fully analyze the implications of various transportation investments on both travel characteristics and emissions.

Another need that this initiative will address is for an increased understanding of the relationship between transportation systems and land use decisions. This effort will support the development of analytical tools that MPOs and other transportation decision makers can use to assess the implications of transportation projects for overall sustainability, including land use, economic development, and accessibility.

II.3.b. Next-Generation Vehicles

II.3.b.i. Next-Generation Motor Vehicles and Ships

There are four prominent national concerns which, together, will require significant advances in transportation vehicle technology. First, the U.S. relies on petroleum to provide more than 95 percent of the energy required for transportation, and it has been estimated by some researchers that even a brief supply curtailment (i.e., 2 years) could drain $500 billion from the economy. Second, although the U.S. has advocated the adoption of binding international commitments to stabilize the atmospheric concentration of greenhouse gases, continued growth of U.S. transportation sector emissions is projected under current policies. Third, while recent improvements have been realized in urban air quality, additional measures for mobile sources would be required to meet tighter proposed standards for ozone and fine particles. Finally, U.S.-based component and vehicle manufacturers face growing international competition, and must continue to make technological gains to compete effectively in the world marketplace.

Initiative: Next-Generation Motor Vehicles and Ships.

Goal: Develop internationally competitive, domestically produced motor vehicles and ships that achieve unprecedented gains in fuel efficiency, environmental performance, and operational performance.

Participants: DOT (FTA, FRA, MARAD, NHTSA, Coast Guard); DOC; EPA; DARPA; DOE; state and local authorities; National Laboratories; universities; component suppliers; fuel producers; engine and vehicle manufacturers; fuel cell producers; and new energy conversion technology manufacturers.

Benefits: Reduced economic vulnerability to petroleum supply curtailments; reduced emissions of greenhouse gases, ozone precursors, and fine particulate matter; improved transit service; improved intercity transportation service in high-density markets with airport capacity and landside access constraints; improved global competitiveness of U.S. truck, bus, and locomotive manufacturers; establishment of domestic manufacturers as leaders in production of new energy-conversion systems; revitalization of U.S. maritime carriers and shipyards; and provision of surge capacity essential to national security.

This partnership initiative responds to these concerns through R&D leading to the development of transportation vehicles that are more efficient and far less polluting. Specifically, this effort will seek to develop the next generation of:

Highway Vehicles: This initiative will continue the PNGV and Advanced Technology Transit Bus (ATTB) activities and will supplement them by also focusing on dramatic improvements in medium- and heavy-duty-vehicle fuel efficiency. This complements, and must be coordinated with ongoing research supporting the establishment of effective safety regulations applicable to such vehicles--a core DOT responsibility. In 1993, the Clinton Administration joined in a historic partnership, the PNGV, with the Big 3 automakers to establish global technical leadership in the development and production of affordable, fuel-efficient, low-emission automobiles that meet today's safety and performance standards. However, while automobiles account for 40 percent of the nation's transportation energy demand, heavy vehicles—buses and trucks—still consume 25 percent of the total energy used for transportation. These vehicles, which tend to use diesel fuel, are also responsible for major shares of transportation sector emissions of nitrogen oxides and fine particles. In recent years, the FTA has worked collaboratively with the transit industry to develop the first prototype ATTB. This bus uses lightweight composite materials and an electric drivetrain to achieve a four-to-five–ton reduction in curb weight, low emissions, and reduced fuel consumption.

Locomotives: DOT's Strategic Plan calls for the development of high-speed rail as a viable transportation option in select corridors. The primary market for this service is generally perceived to be trips of from 100 to several hundred miles in length. Although many routes may well prove viable for higher speed trains—in the range of 100 to 125 MPH or faster—applications in the U.S. require a non-electric high-acceleration locomotive. Although most high-speed technology uses electric propulsion, virtually the only portion of the U.S. rail system currently electrified is the Northeast Corridor—and the cost of electrification is daunting. This partnership initiative will support the development, test, and demonstration of non-electric, high-speed rail technology to establish a technological context in which public agencies and private industry can proceed to implement new rail services.

Ships: International freight transport is critical to this country's participation in the global economy. Total oceanborne foreign trade in 1994 had a value of $566 billion, up 13 percent from the previous year. Moreover, commercial sealift is the primary means of deploying military assets abroad. Sufficient surge capacity, including readiness for conversion of ports and a portion of the commercial fleet from civil to defense functions, is therefore essential to national security. It is thus important to the nation that there be a U.S. merchant fleet capable of competing internationally on a cost and service basis. By supporting focused R&D designed to stimulate and foster innovation in ship design and shipbuilding, this initiative will provide Federal participation and leadership necessary to ensure national defense readiness and to restore the health of the U.S. maritime industry. This includes not only ship structure but also ship propulsion. For example, recent Navy demonstrations of fuel cells could form the basis for a partnership with the Coast Guard to develop this technology for wider use in ships and, potentially, for land transportation vehicles such as locomotives, buses, trucks, and automobiles.

II.3.b.ii. Aviation Safety Research Alliance

Great strides have been made over the past 40 years to make flying the safest of all of the major modes of transportation. Aviation accidents have leveled off at extremely low rates. However, although the accident rate is very low, it has stayed relatively constant for the past decade or so. Moreover, the significant projected growth in air traffic in response to global demand has the potential to cause the total number of accidents to rise dramatically throughout the entire aviation system over the next 20 years.

Initiative: Aviation Safety Research Alliance.

Goal: Provide the technology to reduce fatal aviation accident rate by a factor of five in 10 years and a factor of 10 in 20 years.

Participants: NASA, DOT (FAA), DOD, airlines, manufacturers, universities.

Benefits: Reduced aviation accidents and accident- related fatalities and improved capacity to meet safely the growing world demand for air transportation.

This partnership initiative addresses these long-range issues proactively through an alliance between government and industry to develop and deploy innovative technologies and products that (1) reduce human-error-caused accidents in aviation by a factor of ten over 20 years; (2) eliminate hazardous weather as a cause of aviation accidents; and (3) reduce by half accidents due to malfunctions of safety-critical aviation systems. The FAA will continue its research that focuses on addressing immediate operational safety issues and results most frequently in safety- critical rulemaking. In contrast, the innovations that will be the outcomes of this research alliance will be developed for incorporation by industry as new products in future aircraft or as additions or alterations to existing aircraft or procedures. Specific areas for this long-range technology development include:

Aircraft Systems: Prevent malfunctions of aircraft equipment and systems through innovations in aircraft design, manufacture, monitoring, inspection, and repair prior to malfunction.

Human Factors: Eliminate human- caused mishaps through human- centered aircraft and system design, alternative procedures and processes, and improved education and training.

Environment: Ensure separation between aircraft and hazardous weather, terrain and obstructions, other aircraft and their wakes, and hostile action (military/security).

II.3.c. Transportation Physical Infrastructure

II.3.c.i. Total Terminal Security

The years since the outbreak of Middle Eastern terrorism in the 1960s have seen an intermittent cycle of both increases and declines in major incidents of public terrorism or violence throughout the world. The occurrences of such incidents is often, of course, heavily dependent on local or regional political circumstances. However, recent events in both the U.S. and other parts of the world—including the bombings of the World Trade Center, the Federal Building in Oklahoma City, and Olympic Park, and several attacks against transit operations in such widely scattered cities as Tokyo, Paris, and Baku—have focused considerable attention on the vulnerability of transportation facilities and the potential for another upsweep in the number and severity of terrorist attacks.

> **Initiative:** Total Terminal Security.
>
> **Goal:** Develop a standardized approach to assessing the security threat at transportation facilities and implement a standard security package specifically tailored to that level of threat.
>
> **Participants:** DOT, the intelligence community, domestic law enforcement agencies, state and local transportation and law enforcement agencies, airport and port authorities, and public and private transportation service providers.
>
> **Benefits:** Greater security for transportation users and operators through the development of a standard approach for assessing vulnerabilities and risks at transportation facilities and the collection of valuable information regarding cost-effective allocation of security resources and implementation of security measures.

Because of their visibility, transportation facilities and operations have frequently been the target of such incidents. It is only prudent that transportation officials carefully study the potential threat to their own facilities and operations and develop cost-effective measures that can be taken to minimize the number and severity of incidents. Doing so, however, will require the participation and assent of all agencies and organizations active in this area, including Federal, state, and local agencies with transportation, law enforcement, and threat-analysis responsibilities; airport and port authorities; and private transportation service providers.

This initiative will modify an approach taken by the State Department for application to major transportation terminals, facilities, and operations. This concept, called "Total Terminal Security," will enable the transportation community to apply a standard, acceptable methodology to the allocation of security resources and implementation of security measures at each location. In practice, this concept will cover the range of major security elements, including physical security and public access controls, personnel security, perimeter security, technical security, and, where relevant, communications and information systems security.

One example of a transportation facility to be included in this approach is domestic airports. Under this initiative, new systems for detecting weapons and explosives will be incorporated with other developments in physical security and passenger profiling into a “package” implemented at three to five airports to assess its effectiveness as a total integrated system. The selected airports will become operational laboratories for validating the integration of airport and airline security, new security technology, and the participation of various organizations such as local government agencies, the Federal Bureau of Investigation, and others. Using three to five different airports will help to identify problems that may arise when the total security concept is applied to specific airports. The airports’ security systems will be evaluated in terms of passenger and cargo throughput, delay time due to the inspection process, and operating costs. If the total security concept works as well as expected, the test airports will serve as models for the rest of the Nation’s airports and for the international community.

This airport security activity is already well under way. The Federal Aviation Administration has accomplished simulations of total security packages and, based on these simulations, has developed projected deployment plans. This initiative would expand current work to the three to five operational tests at airports and develop similar integrated security packages for other transportation facilities, including shipping, rail, and transit terminals.

II.3.c.ii. Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure

The Nation’s transportation infrastructure is aging—its elements either nearing or exceeding their design life. This aging infrastructure must be incrementally restored, renewed, and strengthened. Many elements also require capacity expansion if our growing needs for transportation are to be met. Yet, there is a pressing need to “do more with less” in maintaining the physical infrastructure for surface, air, marine, and multimodal nodes in transportation. The DOT Report to Congress, *1995 Status of the Nation’s Surface Transportation System: Conditions and Performance,* estimated that an annual investment of approximately $57 billion would be required from all sources just to maintain current conditions, with $80 billion required to provide a higher level of service by correcting existing deficiencies, including expanding capacity. Moreover, several major airports, which were not addressed in this report, suffer from severe and growing landside congestion delays and capacity shortfalls, while more than $4 billion is spent each year to maintain, repave, and expand existing runways.

Reducing the backlog of needed infrastructure rehabilitation and renewal, and meeting the critical need for improved infrastructure performance and capacity, poses major challenges in terms of life-cycle cost, safety, reliability, and environmental impacts. The growing maintenance funding gap can be bridged only by restructuring the technology base for physical infrastructure renewal.

Initiative: Monitoring, Maintenance, and Rapid Renewal of the Physical Infrastructure.

Goal: Stimulate and facilitate the effective use of both innovative and conventional construction designs, structures, materials, and methods in the rehabilitation, renewal, and replacement of the physical transportation infrastructure.

Participants: DOT, DOD, DOC (NIST), NSF, CERF, transportation construction firms, manufacturers, state and local transportation agencies.

Benefits: Improved safety and economic productivity of the physical infrastructure through reduced likelihood of catastrophic failure, lower life-cycle investment for system renewal and expansion, and fewer service interruptions.

This initiative proposes strategic joint R&D investments in key technologies to ensure the safe operability of the aging infrastructure and timely detection of deteriorating conditions. These infrastructure technologies fall within three areas:

Renewal Engineering: This technology area covers the use of improved materials, designs, and methods for infrastructure. Specific technologies include new construction methods such as automation and robotics, trenchless and other advanced tunneling, and efficient cut-and-cover; advanced structural materials, including durable composites and metal-composite hybrids; and advanced paints and spray coatings.

Advanced Infrastructure Inspection, Monitoring, and Maintenance: Included in this technology area are nondestructive test and evaluation technologies and “smart” sensors and materials, such as embedded fiber optics for visual inspection or strain interferometry, shape-memory alloys, and ultrasonic or magnetic corrosion detection.

Environmental Engineering and Technologies: This area promotes the use of recyclable materials and environmentally benign technologies to prevent or mitigate the adverse environmental impacts of infrastructure construction and operation. These materials and technologies include green barriers to shield noise and improve air quality; paint and spray recovery systems; non-toxic and recyclable bridge and road coatings, asphalt mixes, and additives; geotextiles for slope stabilization and surface-life extension; and use of recycled tires, plastics, and pavements in infrastructure applications.

II.3.c.iii. Environmental Sustainability of Transportation Systems

Transportation systems have been recognized as having major impacts on environmental sustainability. The transportation sector accounts for about one-third of domestic contributions to greenhouse gas emissions and is the fastest growing contributor both domestically and internationally. Transportation sector impacts upon the health of soils and aquatic resources, as well as habitat disruption, are often irreversible, with unknown long-term ecological consequences. The land use decisions made by governments and individuals are long- lasting and to a large extent determined by the availability of inexpensive transportation choices.

Initiative: Environmental Sustainability of Transportation Systems.

Goal: Investigate the technological and behavioral implications of alternative transportation infrastructures and development patterns to determine those that minimize impacts on long-term environmental sustainability.

Participants: DOT, EPA, DOE, HHS, HUD, the private sector, academia, nongovernmental organizations, and state and local government agencies.

Benefits: Improved ability to understand the linkages between transportation and the environment, and how more sustainable transportation systems benefit society.

These issues are not easy to address and create substantial challenges for the research community. Finding solutions that enhance the sustainability of transportation systems requires applications of technology as well as an understanding of the behavioral and social sciences. Research is needed to determine the technology necessary to design transportation systems and development patterns that provide access to economic, social, and recreational opportunities such that permanent (i.e., unsustainable) environmental degradation is minimized or avoided.

Examples of potential research areas under this initiative are:

Behavioral research associated with development patterns: Technical solutions for devising development patterns that produce environmentally cleaner and safer environments are a means of reducing vehicle-miles of travel (VMT) both to reduce environmental problems and to increase the safety of communities. Research is needed to determine how aspects of human behavior such as mode choice, travel demand, and driver behavior are affected by development scale, the scale of hierarchical transportation infrastructures, and their interaction.

Impacts of transportation infrastructure on climate change: Providing additional transportation capacity "induces" or attracts new trips, as acknowledged by the recent Transportation Research Board special report, Expanding Metropolitan Highways. Both short-term and long-term effects tend to reduce any initial travel- time benefits associated with increases in capacity. Additional research is needed to clearly document both short- and long-term effects, especially the implications for greenhouse gas emissions. Research is also needed to determine whether transportation infrastructure can be designed in concert with development patterns such that accessibility is maximized.

Information technologies and sustainable development: Many information technologies offer solutions that can increase the sustainability of transport systems, especially when combined with development patterns that are more sustainable. For example, telecommuting offers the promise of accessibility without mobility and may be particularly beneficial for promoting development of sustainable communities. Research into the behavioral implications of telecommuting and other information technologies, such as adaptive transit dispatching, can identify the implications for sustainability, such as whether they result in major changes in travel demand and patterns.

Infrastructure needs associated with revitalizing urban areas and cleaning up brownfield sites: Brownfields typically are abandoned and mildly contaminated sites that require minimal clean-up efforts. Redevelopment of these and other urban sites can promote sustainability by avoiding development of ex-urban greenfields. Urban infill development can reduce the need for building ex-urban transportation infrastructure and reduce VMT growth. Urban brownfield sites also often have unmet infrastructure requirements that need to be addressed. Technological solutions, such as information technologies, may be able to identify and facilitate clean-up requirements while providing a transportation solution for abandoned urban areas.

Sustainable freight movement: Efforts to reduce traffic congestion and emissions in urban areas have often taken the form of restrictions on freight movement in favor of facilitating (primarily single-occupant-vehicle) personal travel. Additional research is needed on the long-term regional economic and environmental impacts of current freight policies and opportunities provided by new information technologies, intermodal facilities, and market-based measures for improving the energy efficiency of freight movement in urbanized areas.

Overall, this partnership initiative will address the sustainability of building and operating the interrelated and complex systems of transportation and development that drive, and are driven by, economic activities. The focus will be on behavioral sciences and interactions with technology in determining how people react to different systems to achieve sustainability.

CHAPTER 4

DEVELOPMENT OF THE ENABLING TECHNOLOGY BASE

Innovations in transportation generally result from application of a wide range of scientific and engineering disciplines not specific to transportation. Continual research in these areas is necessary to provide a solid foundation for the steady advances in transportation technology required to meet the demands of the 21st century. Yet, the long-term nature and often diffuse benefits of such research means that market forces may be insufficient to motivate private investment. Moreover, while many Federal agencies conduct research in these areas, that R&D is typically focused on the agencies' specific concerns—not on broader national needs. As stated in the General Accounting Office report on *Surface Transportation Research Funding, Federal Role, and Emerging Issues*, as well as by numerous transportation officials, "the current mix of research projects gives too little emphasis to basic, long-term, high-risk surface transportation research." Examples of such research that is conducted by the Department of Transportation include the Crash Avoidance Research and Automated Vehicle Control and Information Systems programs.

The third tier of the NSTC *Transportation Science and Technology Strategy* identifies six long-term research areas. These are consistent with the principles of the President's Committee of Advisors on Science and Technology, meet the criteria listed in the box to the right, and support one or more transportation system elements. These enabling research areas are (1) human performance and behavior; (2) advanced materials; (3) computer, information, and communication systems; (4) energy and environment; (5) sensing and measurement; and (6) tools for transportation modeling, design, and construction.

Criteria for Enabling Research

- Supports long-term national transportation goals.
- Benefits too widely spread for any one company to recover its investment at a profit.
- Cost or risk is too great for any individual company to bear alone.
- Benefits too far in the future to pass threshold of private investment criteria.

In the third edition of this *Surface Transportation Research and Development Plan*, DOT shaped a long-term research agenda that would facilitate realization of the Department's vision and strategic goals by focusing on transportation challenges for the 21st century and identifying priorities for allocation of scarce R&D resources. The report identified sixteen strategic long-term R&D thrusts (Section II, Chapter 4) that, to a large degree, were based upon and incorporated existing R&D activities. The descriptive framework used did not imply any particular new approach or process for implementation. Rather, the report proposed that each thrust area be pursued in a manner based on, and in harmony with, existing efforts.

The NSTC group of six enabling research areas represents a consolidation of the full set of programmatic long-term surface transportation R&D thrusts identified in the third edition of the *Surface Transportation Research and Development Plan*. It also reflects significant prioritization according to the above-mentioned criteria for Federal support. Table II-4-1 illustrates the relationships between the current enabling research areas and the previous long-term R&D thrusts.

	Enabling Research Area					
Long-Term Research Thrust	Human Performance and Behavior	Advanced Materials	Computer, Information, and Communications Systems	Energy and Environment	Sensing and Measurement	Tools for Transportation Modeling, design, and construction.
Transportation System Assessment and Knowledge Base	**X**		**X**		**X**	**X**
Intermodal Freight Transportation			**X**			**X**
Revitalization of the U.S. International Freight Transport Industry			**X**	**X**		
Improved Materials, Designs, and Methods for Renewal Engineering		**X**			**X**	
Advanced Technologies for Inspection, Monitoring, and Maintenance of Vehicles and Infrastructure			**X**		**X**	
Application of Information Technologies to Transportation Systems Operations	**X**		**X**		**X**	
Advanced Technology for Intermodal Public Transit Systems		**X**	**X**	**X**		**X**

Technical Foundation for High Speed Ground Transport Systems	**X**		**X**	**X**	**X**	
Accident Avoidance	**X**		**X**		**X**	
Accident Survivability		**X**	**X**			
Safety Data and Analysis	**X**		**X**			**X**
Security in Surface Transportation	**X**		**X**		**X**	
Environmental Impact Data, Models, and Knowledge Base			**X**		**X**	**X**
Environmental Engineering and Technologies		**X**		**X**		
Accessibility for Persons with Personal Mobility Limitations	**X**		**X**			
Intermodal Transit System Innovation	**X**		**X**			

Table II-4-1. Relationship between Long-Term R&D Thrusts and Enabling Research Areas

II.4.a. Human Performance and Behavior

For transportation systems to achieve high goals for performance and cost, their design, realization, and use must be based on (1) extensive knowledge of user needs; (2) limitations associated with human performance and behavioral characteristics; and (3) understanding of the many factors affecting the interaction between humans and automated systems.

Human error or inadequacy in vehicle or system operation, maintenance, or inspection is a leading factor contributing to safety and security problems. This arises in part because basic system design, operational procedures, or training programs do not take fully into account the characteristics likely among the people responsible for operating the system. Research in the behavioral sciences provides a critical foundation for building the needed transportation knowledge base to avoid such flaws.

Better understanding of human behavior is particularly needed in system control and operations, including the effects of fatigue, work–sleep cycles, working environment, boredom, and drug and alcohol use; response to emergency situations; testing of readiness to perform duties; and interactions among co-workers. In addition to affecting safety, problems associated with these topics cause operational inefficiencies that lower overall productivity. A broadly based research program will yield behavioral science results and methodologies for all modes of transportation, enabling more efficient use of scarce resources.

II.4.b. Advanced Materials

Technical advances in the defense and consumer sectors have produced a rich inventory of materials and associated structural concepts, tools, and techniques for their use. Enabling research in this area supports applications to transportation infrastructure, including the demonstration of effectiveness and long-term viability and, often, the reduction of costs to a competitive level. Examples include high-performance concrete, new steel alloys, innovative composite materials and adhesives, imaginative structural concepts, computer-aided design techniques, automated construction and maintenance tools, and new approaches to corrosion protection and control.

Similarly, transportation safety and energy use are greatly influenced by the materials from which aircraft, ships, and surface vehicles are manufactured. For example, the PNGV seeking a three- fold increase in automobile fuel economy is exploring the use of high-performance steel, aluminum, magnesium, and glass- and carbon-fiber composites for body structures. Each potential application of an innovative material poses new challenges in terms of material cost, manufacturing processes, joining and adhesives, characterization of failure mechanisms, environmental concerns, and costs compatible with transportation uses.

II.4.c. Computer, Information, and Communication Systems

Worldwide, transportation is being transformed by the growing overlay of an information infrastructure on the existing physical infrastructure yielding a system in which information technologies and ready access to many types of information are integrated into virtually all elements and functions to enable greater efficiency, safety, and improved performance. Effective and rapid exploitation of these innovations will require a substantial and ongoing enabling research and development effort associated with system concepts, characterization of alternative configurational and technical choices, and development and harmonization of a wide range of standards.

For example, increased use of wireless communication throughout the society and economy will require a solid technical and economic knowledge base to support policy decisions regarding allocation and efficient use of electromagnetic spectrum and sophisticated mobile data communications technologies. Similarly, many important transportation applications use the highly-accurate Global Positioning System for position-finding and navigation. Many technical as well as financial and institutional issues must be resolved to assure that this system evolves and is managed in a manner that fully reflects the growing needs of civil transportation users. The basic standards for electronic data interchange, database synthesis, and system interoperability are being addressed by appropriate trade and technical organizations, but the Federal Government has a critical role to play in facilitating that process.

The growing complexity of intelligent systems and ever greater dependence on them for human safety and functioning of the society will require a high level of reliability and robustness.

Similarly, a transportation system permeated with information technologies has significant new vulnerabilities to terrorist and other malicious attacks. Coordinated Federal research is needed in software modeling and verification techniques and High-Confidence Systems—information systems that provide users with high levels of security, reliability, and restorability. High- Confidence Systems are resistant to failure and malicious penetration or damage, and respond to interference via adaptation or recovery.

Information technology also plays a critical role in technology integration which is essential to rectify current inadequacies in system assessment, policy research, and intermodal research, as well as the widely supported needs in basic, long-term, high-risk research.

II.4.d. Energy and Environment

Economic and environmental characteristics of transportation vehicles are determined to a large degree by the means by which stored energy is provided and converted into kinetic energy. Each candidate technology is typically of potential relevance to at least several modes of transportation, and many have the ability to improve both energy efficiency and emission characteristics. Research in this area includes electric propulsion and battery concepts, advanced internal combustion engines, hybrid designs, and incorporation of innovations such as fuel cells and flywheel energy storage. As discussed above in *II.3.b.i.*, one promising example for which a near-term partnership may be warranted is the Diesel-fed fuel cell demonstrated recently by the Navy--another such example is the FTA fuel cell transit bus program. A variety of alternative fuels are possible, each with strengths and weaknesses in terms of economics, practicality, and indirect impacts. Market forces tend primarily to motivate propulsion system research for near-term application, necessitating cost-shared Federal R&D—such as the PNGV— to explore the longer term and higher risk technologies.

II.4.e. Sensing and Measurement

The wide range of information technologies now being incorporated into transportation systems has steadily increased the value of real-time monitoring and inspection of transportation vehicles and infrastructure. "Smart structures"—roads, bridges, runways, tunnels, and others with a network of embedded sensors—can yield lower cost with increased safety margins by continually providing detailed condition status and information, under normal as well as abnormal circumstances. "Smart vehicles" similarly depend to a large degree on sensing their environment and operating circumstances, processing that information, and communicating with other “smart” structures and vehicles to coordinate responses. The benefits of coupling sensing, computing, and communicating in this manner include safety, vehicle and infrastructure lifetime, and optimized maintenance practices.

Monitoring of weather and air quality has direct application to transportation. These examples make clear the value of low-cost, high-performance devices to make an extremely wide range of physical measurements, which can then be coupled to computer chips capable of generating warnings or adjusting operation directly. A virtually unlimited number of physical mechanisms and sensing concepts are potentially available, but devices of special importance to transportation will be identified and brought to fruition only to the degree that the transportation community makes these needs known and establishes their potential economic and operational value.

II.4.f. Tools for Transportation Modeling, Design, and Construction

Enabling research in this area provides tools, knowledge, information, and techniques to improve dramatically the efficiency and effectiveness of (1) assessing system requirements; (2) planning and designing system improvements; (3) evaluating alternative operational concepts and strategies; (4) estimating performance characteristics likely to result from innovations; and (5) managing system operations. Specific areas of research include:

Transportation System Design Tools: Tools and methods—such as computer models and simulations and computer-aided design, integrated across all institutions involved in the planning process—that support system planning and design, including process re-engineering, with emphasis on broad system engineering and integration to assure that the resulting system makes effective use of all components in efficiently achieving a high level of performance.

Characterizing and Modeling System Performance and Impacts: Means by which system performance—such as mobility, safety, security, and economics—is measured, assessed, and integrated into system design and operation processes and decisions.

Transportation and Logistic System Operations and Management: Information technology and other tools to support operation and management of transportation and logistic systems, and to assure seamless integration across organizational, modal, and institutional interfaces.

Transportation Planning, Economics, and Institutions: Development of a broad knowledge base and identification and characterization of needs and interests of all parties involved with the transportation system; understanding the economic, financial, and institutional context for transportation.

CHAPTER 5

EDUCATION AND TRAINING

The Nation’s investment in research and technology is critical to the transportation system’s safety, efficiency, and capacity to support national goals. Equally important, however, is our continuing investment in the human capital, the transportation professional and worker, who is responsible for the design, construction, operation, and maintenance of the system.

The Federal Government has long supported transportation education. Current programs administered by DOT are crucial to ensuring the professional capacity of the transportation enterprise. The University Transportation Centers Program, the Eisenhower Fellowships, the Aviation Education Program, and the National Highway and National Transit Institutes are representative of the Government's continuing investment in transportation education and professional enhancement.

Through these programs, the Department supports the development of trained transportation professionals; sponsors the pursuit of promising research efforts, many of which address immediate and practical system needs; and provides a stimulus to small and minority-owned businesses capable of addressing high-priority research issues confronting transportation.

Transportation today is undergoing great change—experiencing advances in technology, undergoing organizational transformation, and continuing globalization along with the world economy. These changes require that current and future generations of transportation professionals and workers be responsive to a dynamic environment:

- *Advanced Technology*: Transportation technology once focused on traditional building materials, standard construction techniques, and combustion-engine-powered vehicles. Newly developed and deployed transportation technologies reflect advances in telecommunications, information systems, energy storage, and advanced electronics and materials. The transportation professional and worker must be educated and trained to adapt these technologies to the existing transportation infrastructure, and to take advantage of new operational practices as a means to provide capacity that, in the past, would have been added through the construction of new physical infrastructure. Moreover, these new technologies require the workforce’s capacity to provide a supply of new workers, as well as train many existing workers, to operate and maintain these new systems.

- *Organizational Transformation*: The transportation organizational environment continues to change, and there is an accelerating shift away from construction of new physical facilities, and toward management practices that achieve operational efficiency gains, often through the application of information technology. ISTEA began the trend toward devolution of authority to state transportation agencies. Likewise, the movement toward intermodal planning, finance, and operations has resulted in many highway departments evolving into state "transportation" departments. These new agencies are only now learning to address the competing needs of regional public mobility and freight movement with environmental and societal concerns. The combined impacts of devolution and transportation agency changes demand that professionals be taught the most effective and innovative management techniques.

- *Globalization:* Transportation continues to reflect a global economy. Business manufacturing and logistics chains now rely on the transportation operations and facilities of many countries. Likewise, increased world business and leisure travel requires that transportation professionals be aware of changing customer needs. For example, Japan, France, and Germany require their university transportation students to work in transportation abroad prior to graduation to provide them with a better understanding of global transportation operations.

These changes in transportation demand new initiatives to address the evolving needs of the transportation workforce. The NSTC *Transportation Science and Technology Strategy* defines four key education and training initiatives that meet the criteria listed in the accompanying box.

Criteria for Education and Training

- Build professional capacity of industry and State/local transportation agency staffs.
- Create general public awareness of transportation benefits.
- Ensure a globally competitive workforce.
- Prepare next-generation transportation professionals with multi-diciplinary education.

II.5.a. Introduction of Transportation Concepts: Elementary and Secondary Education

Transportation permeates every aspect of the nation's economy, yet little effort is made to show elementary and secondary students the connection between their studies and the transportation systems around them. Many students are lost to the transportation profession simply because they have been given no incentive to pursue subjects such as math and science that are essential to advancing in the field. Of even greater importance is the school system's responsibility to produce citizens capable of making informed choices in a democracy. We are shortchanging ourselves and our posterity when we fail to provide our young people with the knowledge of how transportation systems connect them to each other and the world. This initiative will stimulate collaborative public–private partnerships to assist educators in developing and delivering transportation education modules that are fully integrated into the curriculum for each grade level.

II.5.b. Vocational and Technical Training

Transportation has been and continues to be a major source of the nation's jobs. The need for well-trained and efficient transportation workers is crucial to the safety and competitiveness of the transportation system. This initiative supports collaborative investments with vocational schools, community colleges, and industrial training institutes to ensure a steady supply of capable workers to the transportation enterprise.

II.5.c. Transportation Degree Programs: International and Multidisciplinary

This initiative will build upon existing DOT programs to foster the development of transportation degree programs based on multidisciplinary curricula. In the face of increasing globalization of transportation, the nation's institutions of higher learning must prepare their graduates to deal with transportation as a complex issue of systems with global dimensions. This program will assist universities in their development of multidisciplinary programs focused on identifying and resolving transportation issues in an increasingly international arena.

II.5.d. Mid-Career Transportation Training

Dramatic changes in technology and organizational transformations have left many transportation professionals and workers unprepared. Where technologies and training once changed only every 20 years, today the half-life of rapidly advancing technologies may be anywhere between 3 and 5 years. Such rapid development requires that current workers and professionals be educated in the latest technological advances in ITS, diagnostics, materials, command/control systems, and related applications. Likewise, transportation agency managers require the management tools necessary to meet their new responsibilities and evolving missions. This initiative will ensure that the current generation of transportation workers and professionals has the capacity to apply the most innovative technologies and techniques.

CHAPTER 6

MEASURING SUCCESS AND ESTABLISHING FUTURE DIRECTIONS

II.6.a. Performance Measurement

Over the past several years, the use of performance measures to evaluate program effectiveness as a key feature of performance-based management has increased dramatically, both in the public and private sectors. The ongoing “re-engineering” of American business and industry has placed a premium on performance monitoring and evaluation to establish the impact of changes or restructurings. “Benchmarking” performance, both internally and against competitors, has also become a key managerial practice, as businesses endeavor to minimize unnecessary costs and maximize productivity and competitiveness, both domestically and abroad. Major decision with regard to staffing, markets, product line, expansions and R&D are now made in the presence of carefully developed and maintained performance monitoring systems, to which are tied continuously improved policies, guidelines, and procedures.

Performance-based management concepts are not new to the public sector, although they bear important differences to their private sector counterparts. In the public sector, governments and their agencies practice the concept of “planned program budgeting,” where objectives are set, and budgets are allocated and programs are evaluated in relation to performance against those objectives.

The key differences in application of these principles between private and public sectors may be in the nature of the objectives and, consequently, the types of “things measured.” Businesses must staunchly adhere to a “bottom-line” standard, and hence make hard decisions based on cost and profitability criteria. In the public sector, the criteria are often less clear cut. Public managers are often faced with balancing “social” objectives with physical and economic performance. These social objectives can be difficult to quantify or measure, and imply important political as well as economic tradeoffs.

Notwithstanding these difficulties, public sector performance measurement has grown significantly in the face of resource constraints, and a restructuring of public programs and organizations. The climate in which Federal programs now operate makes clear the need for increased accountability and justification of expenditures and policies.

II.6.a.i. Government Performance and Results Act

Perhaps the greatest force driving these trends in the public sector is the Government Performance and Results Act of 1993 (GPRA), P.L. 103-62, enacted on August 3, 1993. It requires the development and use of performance measures for agency management, and may ultimately provide the foundation for the use of performance measures in allocating budgets. It also requires Government-wide implementation of strategic planning, annual program goal-setting, and annual program performance reporting of expenditures in the federal budget in 1997. Agencies are to develop annual plans, setting performance goals, beginning with FY 1999. The overall schedule for GPRA implementation is shown in Table II-6-1.

Table II-6-1. GPRA Implementation Schedule

October 1993 Designation of agencies as pilot projects for performance plans and reports for FY 1994-1996.

October 1994 Designation of agencies as pilot projects for managerial accountability and flexibility for FY 1995-1996.

May 1997 OMB is to report to the President and Congress on the results of the pilot projects.

September 1997 Agencies submit first annual performance plans for 1999 to OMB. Before the beginning of FY 1998, all agencies are to have completed and submitted to OMB a 5-year strategic plan (updated at least every three years).

October 1997 Designation of agencies as pilot projects in performance budgeting for FY 1998-1999.

January 1998 All agencies are to prepare annual plans setting performance goals, generally expressed in "objective, quantifiable, and measurable" form, beginning with FY 1999.

March 2000 Agencies are to submit annual performance reports for FY 1999 to the President and Congress.

March 2001 OMB reports to the President and Congress on the results of all the performance budgeting pilots and recommends whether or not performance budgeting should be required.

The Department is currently in the process of developing its first performance plan under GPRA. This plan will identify performance goals and measures that, taken as a group and considered along with external factors, will provide valuable insight into the performance of DOT programs. However, many benefits of Federal programs take several years to be realized, and only then are the results reflected in data.

Performance goals are being developed to reflect a high-level view which cuts across the Department. More detailed goals and discussions of how goals will be achieved will be contained in performance plans developed by each of the Department's operating administrations.

The spirit and intent of GPRA is to improve Federal program effectiveness and public accountability by promoting a new focus on results, service quality, and customer satisfaction. The establishment of quantitative performance measures and goals that could be used to effectively manage resources is, however, a nontrivial task. For example, the Department's most important strategic goal is the promotion of safe and secure transportation. There are many different potential measures of safety, each of which has specific merits and deficiencies. Examples of just three potential measures currently under consideration by the Department are shown in Table II-6-2:

Potential Measure	Pros	Cons
Per-capita transportation fatalities divided by the overall mortality rate.	Gives broad perspective on transportation facilities.	Sensitive to external changes in the U.S. mortality rate.
Average years of potential life lost before age 65 due to transportation accidents.	Magnitude of years of potential life lost to transportation accidents demonstrates the tremendous benefit to society of transportation safety programs.	Implied emphasis on preventing the untimely death of young people may not be acceptable to everyone.
Number of fatalities from transportation accidents.	Easily measured and understood, weights each life equally.	To reduce total fatalities, the transportation system will have to get safer at a faster rate than that with which its use increases.

Table II-6-2. Potential Measures for Transportation Safety

As this table indicates, the choice of measures can reflect different concerns and, perhaps, lead to important differences in policy based on the indicators used. In addition, the establishment of causality for program management can be very challenging when a wide range of policies and programs are implemented over years or decades, during which time an even wider range of external factors can influence results or outcomes.

Through initial development of an overall DOT performance plan, and the publication of a *Transportation Science and Technology Strategy*, the Administration has begun to identify broad performance goals and measures for the National transportation system. A preliminary set of measures associated with the National goals for transportation have already been identified in Table I-1. Several elements of the Department, in particular NHTSA and the ITS Joint Program Office, have identified performance measures for FY 1998 R&D programs before being required to do so under GPRA. However, many of these measures, summarized in Appendix B, are somewhat preliminary in nature, and they may not yet reflect ongoing interagency coordination processes. As such, the Department has deferred presenting them in the remainder of this section of the *Surface Transportation Research and Development Plan*.

II.6.a.ii. Indicators Applicable to Specific Phases of Inputs, Outputs, and Outcomes

Broad long-range planning documents, such as the NSTC *Transportation Science and Technology Strategy* and this *Surface Transportation Research and Development Plan*, emphasize long-term societal goals such as a safer transportation system. Progress toward such goals is measured using broad system-level indicators, an example of which, in this case, might be the total annual number of transportation-related fatalities. It must, however, be understood that progress toward ultimate outcomes results from the combined effects of research, implementation, and external factors. More specific indicators of performance are required at the program level, and these indicators must flow from the system-level goals through a series of intermediate measures.

In *Assessment of Fundamental Science*, NSTC has identified several principles for the assessment of fundamental science programs--these principles are also of value in the initial consideration of applied research that is more typical of transportation R&D. These principles include:

- Clear definition of program goals.
- Development of criteria intended to sustain and advance the excellence and responsiveness of the research system.
- Establishment of performance indicators that are useful to managers and encourage risk taking.
- Avoidance of assessments that would be inordinately burdensome or costly or that would create counterproductive incentives.
- Incorporation of merit review and peer evaluation of program performance.
- Use of multiple sources and types of evidence; for example, a mix of quantitative and qualitative indicators and narrative text.
- Production of assessment reports that will inform future policy development and subsequent refinement of program plans.
- Communication of results to the public and elected representatives.

This report also defines several general categories of performance measures, summarized below in Table II-6-3:

Quantitative	Qualitative
Publication Counts	Merit Review with Peer Evaluations
Patent Counts	International Standing
Citation Counts	
Contributions to Other Goals	
Rate-of-Return, Other Economic Measures	

Table II-6-3. General Categories of Performance Measures for Research

For transportation research and development, performance measures that fall into these general categories are of use in assessing specific programs. However, because many of those programs are more directly oriented toward intermediate and ultimate outcomes, consideration of a wider range of hierarchical performance measures is critical for transportation R&D.

II.6.a.iii. Framework for Measuring the Performance of Transportation R&D

In its *Transportation Science and Technology Strategy*, the NSTC CTRD has developed a tiered approach to planning transportation R&D, which is presented above in Chapter 2. This approach organizes the different realms of research into groups which produce a logical sequence of outputs and inputs--some activities producing outputs that are, in turn, inputs to subsequent activities. This sequence, through interactions with external factors, results in a set of intermediate and ultimate outcomes. Within the context of transportation research and development, this model is illustrated in somewhat more detail below in Figure II-6-1.

As this figure demonstrates, any specific R&D project draws upon a range of resources, and produces research outputs (e.g., technologies), which in turn, can result in outcomes at subsequent stages through subsequent activities. In order to be effective as management and planning tools, performance measures must be appropriate to the hierarchical level at which they are applied:

- At a high level, performance goals and indicators must be established for ultimate <u>outcomes</u> related to the National transportation system.

- For project planning and management, considerably more direct measures of program <u>outputs</u> are needed.

- These program outputs need to be linked to intermediate and ultimate outcomes through a well-chosen series of intermediate measures.

As discussed below, the Department is currently developing measures at all three levels as part of the budget planning process for fiscal year 1999.

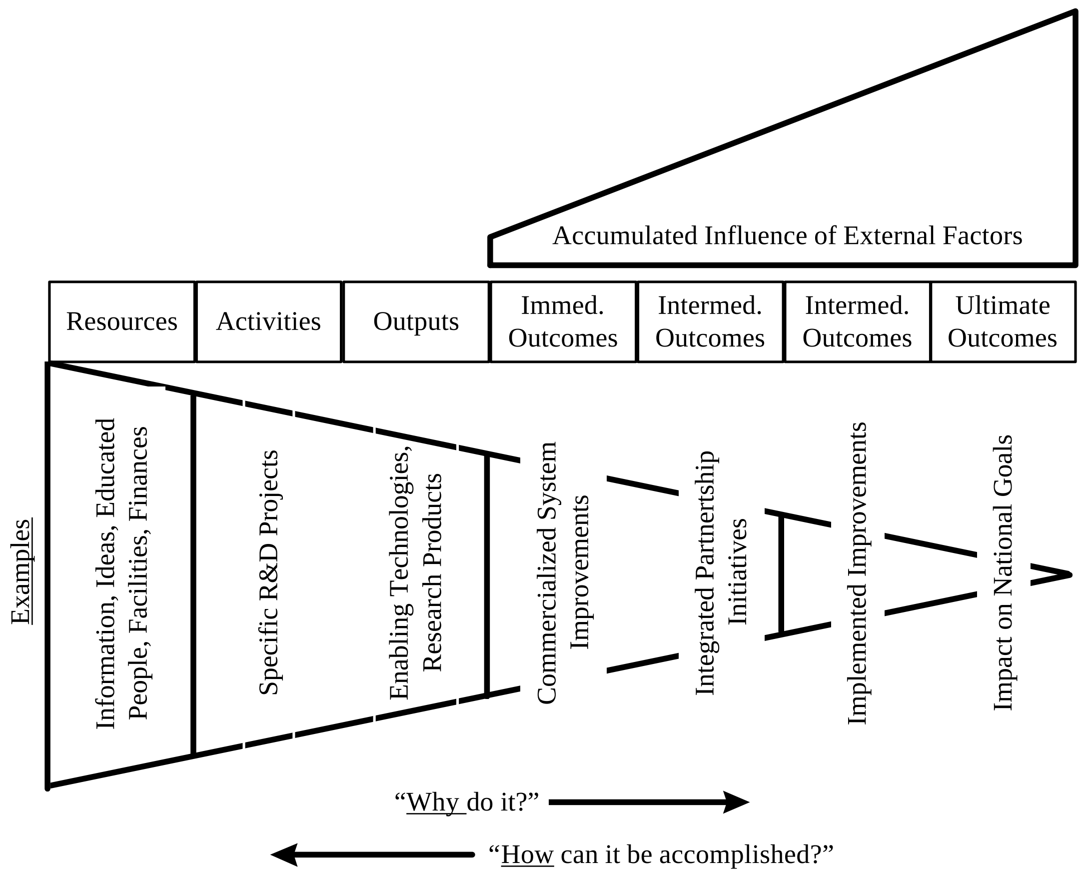

Figure II-6-1. Logical Model for Programs and Outcomes

II.6.a.iv. Research and Development Contribution to Top-Level Goals

In the above-mentioned strategy document, the NSTC CTRD has identified five potential general measures which apply to the National goals for the transportation system, as presented below and in Table I-1.

These high level measures of what are, from a transportation perspective, ultimate outcomes, provide a very general indication of the overall performance of the National transportation system. They apply to all modes of transportation, and to the system as a whole. The focus of this report is on surface transportation only. These measures have a great deal of integrating power--that is, they measure the combined results of both DOT's programs and the full range of external factors, and involve measurement beyond the transportation sector. By the same token, they have very little resolving power, and would be of little use as measures of success of any specific R&D program.

Strategic Goal	**Outcome Measure**
Provide a safer transportation system.	Level of reduction in transportation-related fatalities, injuries, and property losses.
Achieve a high level of transportation system security.	Level of public trust and confidence in the security of the Nation's transportation network as determined through national surveys.
Improve environmental quality and energy efficiency.	Number of major areas not now attaining legislatively-mandated air quality standards that reach these air quality goals by 2020.
Foster economic growth and productivity through global passenger and freight services.	Level of cost-effective passenger and freight throughput.
Ensure improved access to and increased mobility on the Nation's transportation system.	Degree of increased and enhanced access and mobility of the elderly, the poor, and other transportation-disadvantaged populations.

Table II-6-4. National Strategic Goals and Measures for Transportation

The Department is currently considering a wide range of more specific--for example, with respect to mode--potential performance goals and measures applicable to the transportation system, to be used in budgetary planning for fiscal year 1999, per GPRA. In doing so, the Department is following a number of related guiding principles, examples of which include:

- Outcomes are always influenced by external factors beyond the program's or agency's control--performance goals and indicators must reflect how agencies will strive to influence these elements not entirely in their control.

- Goals must be stated in terms that are clearly understandable to one's "next door neighbor."

- Goals must be externally focused--the unique things programs do that provide value to the public.

- Goals must be clearly linked to mission.

- Goals should be ambitious, but realistic.

- Outcome goals should be independent of how they will be achieved.

- Goals and measures are part of a bigger communication process. Communicating the value of programs in terms which are ultimately comparable with other Federal programs will allow high-level decision makers to set government-wide priorities.

- Performance measures must be relevant to senior management, and usable in managing activities and resources.

- Measures must be credible externally--including credible data and a credible program evaluation process.

- Imperfect measures are acceptable. The process is evolutionary.

The Department is currently examining nearly fifty different candidate measures of performance of the National transportation system. In doing so, DOT must consider the degree to which potential measures adhere to the above principles, and must weigh the policy issues, such as that shown in Table II-6-2, which are inherent in the choice of measures. An illustrative and noninclusive list of candidate measures follows:

Performance Aspect	Sample Measure
Accessibility--Coverage	Highway system supply (lane miles, by classification, condition, etc.) per "demand unit" (capita, employee, square mile, VMT)
Accessibility--Proximity	Percent of potential passenger travelers within *x* miles or *y* minutes of specified transportation service (interstate/4-lane highway; local public transit service; intercity bus or rail service; scheduled air service)

Accessibility--"Realistic" or "Functional" Access	Number of persons who can reach a specified destination (local, intercity, international) by applicable mode (transit, intercity bus or rail, scheduled) within specified limiting service parameters (e.g., no more than 1 transfer, no more than *x* hours/minutes of delay, no more than *y*% circuitry)
Quality of Service--Level of Service	Percent of highway lane miles with peak hour volume to capacity (V/C) ratios > 0.9; Change in percent of lane miles which are at V/C > 0.9 (1) outside peak periods, and (2) for expressway facilities
Quality of Service--User Satisfaction	Passenger assessment of level of quality/satisfaction and/or degree of change in: travel time, speed, cost, number of alternatives, congestion, reliability, safety, etc.
Quality of Service--Efficiency	Carrying efficiency of passenger modes (private vehicle persons per vehicle mile; transit passengers per seat-mile, intercity air, rail, bus load factors)
Economic Health and Competitiveness	Cost of transportation reflected in final cost of goods and services (transportation CPI vs. manufactured goods CPI)
Social Equity, Mobility, Quality of Life	Percentage of day devoted to traveling for persons, households
Security	Number of incidents (terrorism, highjackings, theft, vandalism) associated with transportation activities per utilization unit (e.g., per capita, per person-trip, per service operation, per dollar of travel/shipment expenditure, etc.)
Safety	Number of transportation accidents, injuries, fatalities per "demand unit" (e.g., per person-trip, passenger mile, VMT, type of facility, major mode)
Environment	Emissions rates of transportation modes (passenger vehicles, transit, air, rail, freight, modes), current year/models and fleet average
Energy	Fuel consumption rates (mpg or Btu per mile) of transportation modes (passenger and freight), current year and fleet average

Table II-6-5. Sample Performance Measures for the National Transportation System

Over the next several months, the Department will be choosing from these and other performance measures to develop a set that will be the most useful for initial performance-based budget planning.

II.6.a.v. Intermediate Measures

In preparing its fiscal year 1999 budget, the Department will face three fundamental challenges in making explicit its performance-based management of scarce public resources. It must establish a set of overall goals for the performance of the National transportation system, and identify a set of indicators of progress toward those goals. It must begin to identify intermediate measures of performance which, for a given program, go beyond the direct outcomes of that program, but are also less subject than the high-level performance indicators for the transportation system as a whole to the influence of factors external to that program. Finally, the Department must identify means by which the performance of individual programs, including R&D programs, can be measured.

In the example given below in *II.6.a.vi*, a yearly assessment of the extent to which NHTSA's Crash Avoidance Research program has accelerated the development of crash avoidance products by the private sector provides just such an intermediate measure of performance. A major focus for the next several months will be the identification of such measures for the range of the Department's research programs.

II.6.a.vi. Measurement of Outputs

In some ways similar to that resulting from basic research, the knowledge gained through the applied research that is more typical of transportation R&D is not always of immediate value, and is not always applied immediately. For example, a research program may yield a technology which has the potential to prevent a specific type of transportation accident, but the deployment of that technology could be limited by policy considerations (i.e., regulatory agenda) and/or market conditions. As a result, performance measures for transportation R&D may be expressed in terms of direct outputs and more intermediate outcomes.

For example, in its *FY 1995 Performance Report* (March 1996), NHTSA, which was chosen by OMB as a GPRA pilot, identified the following measures for its Crash Avoidance Research: (1) timely dissemination of research results, (2) timely response to short-term rulemaking needs, and (3) acceleration of private sector development of crash avoidance products. Obviously, the ultimate objective of NHTSA's Crash Avoidance Research is the prevention of specific types of collisions--however, these measures of direct outcomes (1 and 2) and intermediate impact (3) will give a much more direct measure of performance of the research program itself.

Initial efforts by DOT operating administrations to develop performance measures for transportation R&D programs have, in general, yielded measures that fall into the general categories identified in the NSTC report on *Assessment of Fundamental Science*, or are similarly specific to direct program outputs. In many cases, R&D programs have also been linked to high-level outcomes they are designed to influence. Appendix B presents a detailed list of preliminary performance measures developed to date by DOT for its R&D programs.

II.6.b. Summary

Strategic planning and assessment--the basis for efficient utilization of scarce public resources--must be pursued on an ongoing basis, and must be founded upon an evolving process for measuring both progress toward ultimate societal goals and performance of specific funded programs. With respect to surface transportation research and development, multi-sectoral and multi-modal top-level outcomes, which can be measured by high-level performance indicators, are the result of technologies and systems that are actually implemented as part of the National transportation system. In the future, such technologies and systems, whose success can be measured by outcome indicators that tend to be somewhat more specific and modally-oriented, will increasingly be developed through partnerships that capitalize on opportunities for private/public resource leveraging. These technologies and systems will be founded upon an enabling technology base that is established and enhanced on a long-term basis, and progress in doing so will be measured both in terms of direct technological outputs and, in some cases, intermediate outcomes. A technologically capable workforce will be a key resource input at this and all higher levels, and success in providing this resource will be measured as a direct output of education and training. Only by committing to regularly measure progress at all levels and conduct strategic program planning and assessment can the Nation ensure the most efficient and effective possible utilization of its resources for surface transportation research and development.